# THE CLAVICHORDS OF HIERONYMUS AND JOHANN HASS

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THE CLAVICHORDS OF HIERONYMUS AND JOHANN HASS


## ABSTRACT

The twenty-five surviving signed clavichords by the Hamburg makers Hieronymus and Johann Hass, covering a period of approximately forty years from 1728 to 1767, represent one of the pinnacles of musical instrument manufacture. From a study of twenty-two of these instruments a number of important clavichord design principles and constructional techniques has been determined. For instance it was found that the construction of the case joints, rack and 8ft bridge were undertaken with the aid of a template, whilst the bridge pins, tuning pins and hitch-pins were positioned using a calibrated stick held perpendicular to the spine. By plotting the pin positions it has been possible to determine the method used by Hass (father and son) to space the pins in various multiples of the Hamburg *Zoll* or inch. Thanks to the family's habit of dating their instruments the evolution of their working methods can be discerned; in general the dimensions of the later instruments of both makers are greater than those of the earlier instruments, but remain in the same proportion. Bridge shape, rack-slot spacing and pin positioning also vary from instrument to instrument, not because of any haphazard approach to construction but rather as the result of an intentional modification and evolution of clavichord design during the making of a large number of instruments. This research has enabled a positive identification of a clavichord in Köping, Sweden, (where the signature and date are no longer legible) as being the work of Hieronymus Hass. The techniques developed for this study can be used in the investigation of other clavichord builders and their work.

## INTRODUCTION

The clavichords of the Hass family display some of the finest craftmanship found in historical musical instruments, and it can be clearly shown that both Hieronymus and Johann Hass took great care over all aspects of construction and decoration of their instruments. The sound of their instruments must also have been greatly admired as both their harpsichords and their clavichords appear to have been exported to places as far apart as the Iberian peninsula and Scandinavia.

According to Raymond Russell writing over thirty years ago[1]:

> [Hieronymus] Hass, with his son Johann Adolf, constituted the most important family of harpsichord and clavichord makers in Germany, both on account of their work, and of its unusually high quality.

In comparison with the hundred or so surviving Kirckman harpsichords or the ninety extant Ruckers harpsichords and virginals, the number of surviving Hass instruments is relatively small. There are ten clavichords and six harpsichords signed by Hieronymus Hass ranging in date from 1728 to 1744, and fifteen clavichords and two harpsichords signed by Johann Hass ranging in date from 1746 to 1767.[2] I have also attributed the C to $d^3$ fretted clavichord in Köping to Hieronymus. Of the fifteen clavichords by Johann, two are very recent additions: the 1754 JH is a five-octave FF to $f^3$ unfretted clavichord newly discovered in Poland by John Koster; and I am informed by Dr Gerhard Stradner that the clavichord listed by Boalch as No.28 under the instruments of the Hass family[3] is presently in private ownership in Germany. There is no way of being sure that the surviving instruments form a

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1 R. Russell, *The Harpsichord and Clavichord* (London: Faber and Faber, 1959), p.99.

2 The date of the double-manual harpsichord by Johann Hass at the University of Yale is questionable. The dates of 1710, 1750 and 1770 have been given by various writers, but the museum staff now believe the date to be 1760.

3 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840* (Oxford: Clarendon Press, 1974), p.64.

representative sample, but the instruments display a number of common characteristics, from which it is possible to draw a number of conclusions.

There were two basic models of clavichord made by the Hass family during their working careers; the double-fretted C-$d^3$ instruments, and a larger unfretted FF-$f^3$ design. Within these models, various design elements, such as bridge shape, rack slot spacing and bridge pinning can be shown to evolve over a period of years. In contrast, each of the few surviving harpsichords is unique in its design concept. The harpsichords are built with one, two or three manuals, and with widely differing dispositions ranging from 1x8ft 1x4ft[4], to 1x16ft 2x8ft 1x4ft 1x2ft lute.[5] It therefore appears that clavichords were to some extent mass-produced, whereas Hass harpsichords were probably built individually to order.

Perhaps due to their often elaborate disposition and striking appearance, writers have tended to concentrate on the harpsichords to the detriment of the clavichords. Given that the different models of clavichord form distinct groups and display common features, questions concerning design and constructional methods can be more easily considered. This study will, therefore, concentrate only on the clavichords of the Hass family. Details of Hass harpsichords will be mentioned only where they are relevant (such as in chapter seven devoted to decoration) to the clavichord. It is likely that some of the constructional methods discussed apply equally to the harpsichord, but the individual nature of Hass harpsichords warrants a separate study.

Following the chapters covering an outline history of Hamburg and its stringed-keyboard instrument builders, and the pre-Hass traditions of clavichord building, a chapter will cover the design elements of Hass clavichords. This involves a discus-

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[4] The single-manual harpsichord at Leufsta Bruk Manor House, Leufsta Bruk, Sweden, made by Hieronymus Hass in 17(2)6 has this specification.

[5] The double-manual harpsichord at Yale University, Newhaven, Conn., made by Johann Hass in 1760.

sion of compasses, case dimensions, fretting and stringing. Chapter four is devoted to the construction of Hass clavichords, the organisation of which is based upon the likely order in which the clavichords of the Hass family were built. The following chapter includes an acoustical analysis of Hass soundboards and a discussion of the acoustical effect of the octave strings in the bass. Chapter six is a scientific analysis of the family's working methods, which centres on three new and important ways of analysing clavichords: recording the shape of the 8ft bridge, recording the splaying pattern of the keylevers, and determining the original marking-out sticks for the bridge pins, the hitchpins and the tuning pins. The decoration of Hass clavichords is the subject of chapter seven. Since only a small proportion of Hass clavichords survive in their original state of decoration some of the illustrations for this chapter are actually of Hass harpsichords. The final chapter places the clavichords of the Hass family within the wider context of eighteenth-century clavichord building in North Germany and Scandinavia.

Although many residents of Hamburg (such as church organists, instrumentalists at the Oper-am-Gänsemarkt and wealthy middle-class citizens) must have owned a Hass clavichord, it is very difficult to ascertain the clavichord repertoire in the city at this time. The fundamental problem is that no music published in Hamburg during the lifetime of either Hieronymus or Johann Hass is known to have been expressly written for the clavichord. Rather than specifying clavichord, or harpsichord, organ, or fortepiano for that matter many eighteenth-century sources bear the generic term *Clavier*; it is only really in the works of C.P.E. Bach that, through the use of terms such as *Bebung* or its indication (by slurred dots over a single note), that the clavichord is, without doubt, the intended instrument. Clavichord-owners probably did play the latest keyboard compositions by the contemporary Hamburg composers Georg Telemann, Johann Mattheson and Vincent Lübeck, but their works are more suited to the harpsichord. Consequently, this study does not include a section on the musical aspects of Hass clavichords.

It is hoped that this study will show the extent to which the Hass family perfected the making of clavichords, from the original design stages through to the construction and marking-out procedures and finally the decoration of their instruments. Indeed, much of the research, such as that into the positioning of the bridge pins has only been possible because of the family's impeccable workmanship. In general, clavichord building traditions have not been investigated to the same degree as a certain harpsichord and virginal building one; this study is intended to redress the balance.

## CONVENTIONS

Various commentators have argued that the use of the common foot measurement (the German *Fuss*, the Flemish *voet* or the French *pied*) played an important part in the design concept of musical instruments. There was, however, no standard European unit of length in use during the eighteenth century. Instead, the foot varied from country to country and in German-speaking lands even from town to town.[6] Similarly, the division of the foot into inches (German *Zolle*, Flemish *duimen*, or French *pouce*) was not standardised: in England the foot was divided into twelve inches, while in Antwerp there were two sizes of voet, both of which were divided into eleven duimen.[7] Herbert Heyde's value of 286.49mm for the Hamburg Fuss[8] was found to be consistent by the present author with a wooden folding ruler, dated 1875, calibrated in London inches on one side and Hamburg Zolle on the other.[9] The side of the ruler marked 'Hamburg' is calibrated with twelve divisions per Fuss and both eight and sixteen divisions per Zoll. Using

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[6] Two of the most helpful summaries of the various local units of measure in Europe in the historical period are the *Aide-Mémoire à l'usage des officiers d'artillerie de France*, II (Paris, 1819) p.896ff; and H. Heyde, *Musikinstrumentenbau 15-19 Jahrhundert Kunst-Handwerk Entwurf* (Leipzig: VEB Deutscher Verlag für Musik, 1986), pp.70-8

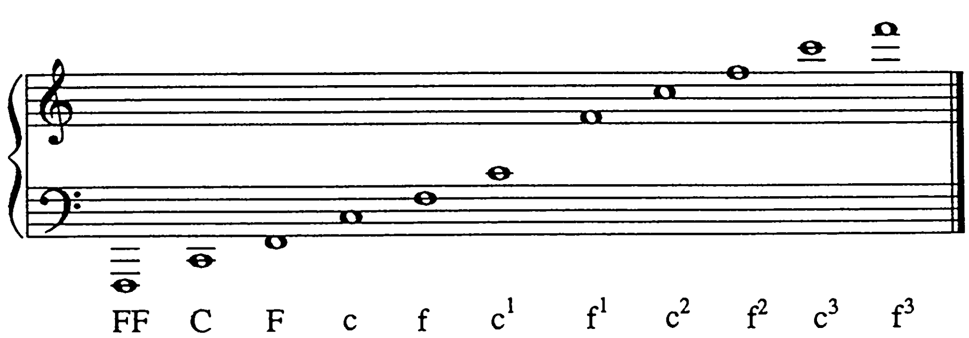
[7] G. O'Brien, *Ruckers, a harpsichord and virginal building tradition* (Cambridge: Cambridge University Press, 1990), pp.284-5.

[8] H. Heyde, *Musikinstrumentenbau, 15-19 Jahrhundert. Kunsthandwerk entwurf.* (Leipzig: VEB Deutscher Verlag für Musik, 1986), p.74.

Heyde's Fuss measurement and assuming twelve Zolle to the Fuss the size of the Hamburg Zoll was calculated as 23.874mm. In all instances where the nominal number of Hamburg inches is quoted it is this value which has been used. Although each Zoll on the Bergedorf ruler was divided into eighths and sixteenths, I have found that the Zoll used in the Hass workshops was divided into twelfths.

All measurements are quoted in millimetres (mm) and follow the usual scientific convention regarding the accuracy of measured results: where the usual accuracy of measurement was to half a millimetre this is given by $\frac{1}{2}$ and not .5 since the latter implies an accuracy of $^{1}/_{10}$thmm.

Although Hass naturally used the German note names B and H for $B^b$ and B, respectively, the British/Helmholtz system of notation is used. This is shown in the staff below:




[9] The ruler, inventory number 53.343, is preserved at Schloss Bergedorf in Hamburg. It was measured by the author as $574\frac{1}{2}$mm for 24 Zolle; and by simple calculation 1 Zoll = $574\frac{1}{2}/24$ = 23.9mm.

The accidental note letter names $C^{\#}$, $E^{b}$, $F^{\#}$, $G^{\#}$ and $B^{b}$ are used throughout the text. The absence of notes from an otherwise normal compass is indicated by a comma. For example a four-octave instrument from C without $C^{\#}$ is written as C,D to $c^{3}$. The usual sixteenth- and seventeenth-century keyboard compass lacked the three chromatic notes $C^{\#}$, $D^{\#}$ and $F^{\#}$ and $G^{\#}$. The apparent notes E, $F^{\#}$ and $G^{\#}$ were tuned to C, D and E respectively, while the notes F and G were tuned as normal and the keyboard was tuned chromatically from the note A upwards. This is notated as C/E bass short octave. The notation used when discussing the fretting of a clavichord is as follows. If the tangent of both the $e^{b}$ and the e keylever strike the same course of strings the two notes are said to be double-fretted; this is indicated by joining the two notes with a hyphen, as $e^{b}$-e. Some instruments have three or even four notes per course of strings, which is referred to as triple- and quadruple-fretting respectively; in these cases all the notes are joined together with a hyphen. If the notes $e^{b}$, e, f and $f^{\#}$ are fretted together, for example, it is notated as $e^{b}$-e-f-$f^{\#}$.

A form of notational shorthand has also been used throughout the text to indicate specific instruments made by Hass and other Hamburg makers: only the date of the instrument and the initials of the maker (in upper case letters) are given. For instance, the clavichord made in 1755 by Johann Hass is referred to as the 1755 JH. Lower case letters are used to differentiate instruments made in the same year. Where the entire date or part thereof is illegible one or more of the digits is given in parentheses, such as (1725) HH. The (1761)d JH is given in parentheses because the instrument only bears an inscription dating a repair of 1761, and I have not yet been able to verify whether or not Johann Hass was the original maker of this instrument.

The system used for footnotes adheres to the format presented in *A Manual of Style*, ed. B. Young & C. Seybold, 12th ed. rev. (Chicago: Chicago University Press, 1969), pp.337-70. The title of a book or periodical is printed in italics. The title of an article in a periodical, a chapter in a book or any unpublished work is, however, given in normal type and enclosed in quotation marks. 'ed.' is used as an abbreviation for 'edited by,' and trans. for 'translated by.' In the following check-list, clavichord and harpsichord are denoted by the upper case letters C and H respectively.

## INDEX OF SIGNED HASS CLAVICHORDS AND HARPSICHORDS

**Hieronymus Hass instruments**

| **Instrument** | **Type** | **Location** |
|---|---|---|
| 1721 HH | H | Göteborgs Historiska Museum, Gothenburg. |
| 1723 HH | H | Musikhistorisk Museum, Copenhagen. |
| (1725) HH | C | Köpings Museum, Köping, Sweden. |
| 17(2)6 HH | H | Leufsta Bruk Manor House, Leufsta Bruk, Sweden. |
| 1728 HH | C | Musikinstrumenten Museum, Berlin. |
| 1732a HH | H | Kunstindustrimuseet, Oslo. |
| 1732b HH | C | Museum für Kunst und Gewerbe, Hamburg. |
| 1734 HH | H | Musée Instrumental, Brussels. |
| 1740a HH | C | Stiftelsen Musikkulturens Framjande, Stockholm. |
| 1740b HH | C | Private Ownership, Copenhagen. |
| 1740c HH | H | Rafael Puyana, Paris. |
| 1742a HH | C | Museum für Hamburgische Geschichte, Hamburg. |
| 1742b HH | C | Museum für Bergedorf und die Vierlände, Hamburg. |
| 1743a HH | C | Bate Collection, Oxford. |
| 1743b HH | C | Musikhistorisk Museum, Copenhagen. |
| 1744a HH | C | Musée Instrumental, Brussels. |
| 1744b HH | C | Stiftelsen Musikkulturens Framjande, Stockholm. |

**Johann Hass instruments**

| **Instruments** | **Type** | **Location** |
|---|---|---|
| 1746 JH | C | Koldinghus Museum, Kolding. |
| 1747 JH | C | Norsk Folkemuseet, Oslo. |
| 1748 JH | C | Grassi Museum, Leipzig. |
| 1754 JH | C | Muzeum Instrumentów Muzycznych, Poznan, Poland. |
| 1755 JH | C | Musikhistorisk Museum, Copenhagen. |

| | | |
|---|---|---|
| 1756 JH | C | Smithsonian Institution, Washington. |
| 1760a JH | H | Yale University, Newhaven, Conn. |
| 1760b JH | C | Museum für Kunst und Gewerbe, Hamburg. |
| 1761a JH | C | Musikhistorisk Museum, Copenhagen. |
| 1761b JH | C | Musikhistorisk Museum, Copenhagen. |
| 1761c JH | C | Private Ownership, Cambridge. |
| (1761)d JH | C | Private Ownership, Germany. |
| 1762 JH | C | Forsyth Collection, Manchester. |
| 1763a JH | C | Russell Collection, University of Edinburgh. |
| 1763b JH | C | Private Ownership, Venice. |
| 1764 JH | H | Russell Collection, University of Edinburgh. |
| 1767 JH | C | Private Ownership, London. |

## INDEX OF SIGNED CLAVICHORDS AND HARPSICHORDS OF OTHER HAMBURG MAKERS

**Dietrich Hass instruments**

| Instrument | Type | Location |
|---|---|---|
| 1796 DH | C | Museum für Kunst und Gewerbe, Hamburg. |

**Johann Fleischer II instruments**

| Instrument | Type | Location |
|---|---|---|
| 1710 JF | H | Musikinstrumentenmuseum, Berlin. |
| 1722 JF | C | Stiftelsen Musikkulturens Framjande, Stockholm. |
| 1723 JF | C | Drottningholm Teatermuseum, Stockholm. |
| 1724 JF[10] | H | Kulturhistoriska Museet, Lund, Sweden. |
| 1728 JF | C | Ringve Museum, Trondheim, Norway. |
| 1729 JF | C | Heimatmuseum, Stade, near Hamburg. |

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[10] The 1724 JF is a re-working of the 1618 Johannes Ruckers double-manual harpsichord.

**Carl Fleischer instruments**

| Instrument | Type | Location |
|---|---|---|
| 1716 CF | H | Museum für Hamburgische Geschichte, Hamburg. |
| 1720 CF | H | Museo de la Musica, Barcelona. |
| 1(72)2 CF | H | Museo Stibbert, Florence. |

**Christian Zell instruments**

| Instrument | Type | Location |
|---|---|---|
| 1728 CZ | H | Museum für Kunst und Gewerbe, Hamburg. |
| 1737 CZ | H | Museo de la Musica, Barcelona. |
| 1741 CZ | H | Museum Ostfriesische Landschaft, Aurich. |

**Johann Gerlach instruments**

| Instrument | Type | Location |
|---|---|---|
| 1756 JG | C | Ringve Museum, Trondheim. |
| 1769 JG | C | Museum für Hamburgische Geschichte, Hamburg. |
| 1780 JG | C | Private ownership, Fischerhude, Germany. |

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Throughout this dissertation I have attempted to credit all sources of information wherever possible. If through oversight I have failed to credit any information given to me by owner, museum curator or organologist I humbly apologize. I am indebted to the many private owners, museum personnel and restorers who have given me information and kindly allowed me to examine instruments in their care. These include: Derek Adlam, Dr Winfried Baer, Dr Martin Elste, Jorunn Fossberg, Göran Grahn, Widar Halén, Miles Hellon, Christopher Hogwood, Dr Gisela Jaacks, Vivi Jensen, Peter Andreas Kjeldsberg, Eva Kjerström-Sjölin, John Koster, Dr Robin Loat, Dr Richard Luckett, Viveca Lundh, Dr Nicolas Meeùs, Jeremy Montagu, Mette Müller, Henrik Nyrop-Christensen, Dr Alexander Pilipczuk, Mr and Mrs Torben Poulsen, Horst Rase, John Raymond, Mr and Mrs Alan Rubin, David Rubio, Dr Winfried Schrammek, Dr Dorothea Schröder, Dr Gerhard Stradner, Barbro Stribolt, Inger Wikström-Haugen, and James Yorke.

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The photographic reproductions are from several different sources: the Musikhistorisk Museum og Carl Claudius' Samling, Copenhagen, Plate 7.1; the Kunstindustrimuseet, Oslo, Plate 7.2; Sotheby's Catalogue, 12th December 1985, No.110, Plate 7.7; the Musikinstrumenten-Museum, Berlin, Plate 7.8; the A.C.L., Brussels, Plate 7.11. The photographs for Plates 4.1 to 4.4 and 7.14 were taken by Grant O'Brien, and the photograph for Plate 7.15 was taken by Peter and Anne MacTaggart. All other photographs were taken by the author. The scaling graphs were drawn by Darryl Martin. The frequency spectra graphs 5.1 to 5.5 are by the courtesy of Raymond Parks. Finally, I would like to thank Jenny Nex for her beautiful illustrations, Plates 7.8 and 7.9.

# Chapter 1

# A BRIEF HISTORY OF HAMBURG

# AND ITS STRINGED-KEYBOARD INSTRUMENT BUILDERS

## A BRIEF HISTORY OF HAMBURG

In the summer of 1723, Georg Telemann (1681-1767) wrote in glowing terms to Johann Friedrich Armand von Uffenbach, town councillor at Frankfurt, of the musical life in Hamburg:[1]

> Was inzwischen die Musik dort bergunter gehet, das klettert sie hier hinauf, und glaube ich nicht, daβ irgendwo ein solcher Ort als Hamburg zu finden, ist der den Geist eines in dieser Wissenschaft Arbeitenden mehr aufmuntern kann. Hierzu träget ein groβes bei, daβ auβer den anwesender vielen Standespersonen auch die ersten Männer der Stadt, ja das ganze Ratscollegium sich den öffentlichen Konzerten nicht entziehen; item die vernünftigen Urtheile so vieler Kenner und kluger Leute geben Gelegenheit dazu, nicht weniger die Opera, welche itzo im höchsten Flor ist und endlich der *nervus rerum gerandarum*, der hier bei den Liebhabern nicht fest angewachsen ist.

> In the meantime, where music declines there [Frankfurt] it is in the ascendancy here, and I believe that nowhere can one find a place where the mind and spirit of one working in this science is more stimulated than at Hamburg. One great factor in this is that as well as the many members of the nobility here, the sensible judgement of so many connoisseurs and clever people provide an opportunity for the city fathers and indeed the whole town council to attend the public concerts. Not least of all there is the opera, which is now in the fullest flower; and finally that *nervus rerum gerendarum* [money] which can hardly be said to be tightly bound to the music-lovers here.

This letter, written just two years after the earliest surviving Hieronymus Hass instrument was constructed, portrays Hamburg as a city where both professional and amateur music-making prospered. Musical activities such as public concerts, music

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[1] G.P. Telemann, *Georg Philip Telemann Musikalische Werke*, ed. G. Fock (Kassel: Bärenreiter, 1953), vol.II, *Der Harmonisches Gottesdienst*, p.viii; R. Petzoldt, *Georg Philipp Telemann*, trans. H. Fitzpatrick (London: E. Benn, 1974), p.53.

publishing and, in particular, the making of musical instruments flourished. All were due to the wealth and importance of the city during the eighteenth century, with many well-to-do merchants, bankers and members of the nobility willing to subscribe to artistic creativity.

Hamburg's wealth at this time had its roots in the twelfth century. The foundation of Hamburg's commercial basis was laid in the autumn of 1188, when a group of businessmen obtained a charter from their feudal overlord Count Adolf III of Holstein, for the construction of a *Neustadt* adjacent to the already existing episcopal town, with a harbour on the River Alster and facilities for the use of the Elbe. On May 7th 1189, in exchange for a contribution towards the cost of a crusade, Adolf III obtained a charter for the town granting various rights and privileges from the Emperor Friedrich I. These included fishing rights on the Elbe, toll exemptions and a separate court; the City Council (*Rat*) had jurisdiction over both towns. A century later, in 1292, the Count of Schauenburg recognized Hamburg as an autonomous state.

Throughout the fourteenth and fifteenth centuries Hamburg grew steadily in both wealth and size. This increase in importance owed much to the development of the Hanseatic League into a widespread association of North German merchant cities. Within the League, Hamburg's role was second only to that of Lübeck, the association's administrative headquarters. Together with Lübeck, Hamburg was an important entrepôt between Russia and Flanders; this stemmed from the two cities' control of the chief link between the Baltic and the North Sea, the overland route across southern Denmark. During the League's heyday, from the late thirteenth to the end of the fifteenth century, it monopolised North European trade; and its importance at this time can perhaps be gauged from a letter from the Scotsmen Andrew Moray and William Wallace to the people of Lübeck and Hamburg:[2]

> Andrew of Moray and William Wallace, leaders of the army of the kingdom of Scotland, and the community of the same kingdom, to the prudent and discreet men, their beloved friends the mayors and commons of Lübeck and Hamburg, greeting and continual increase of sincere affection. It has been announced to us by trustworthy merchants of the said kingdom of Scotland that you, of your own grace and not out of regard for our deserts, are considerate, helpful and favourable in all causes and affairs touching us and our merchants; and therefore we are the more bound to you to give you our thanks and a worthy recompense whereto we willingly engage ourselves to you, beseeching you that they may have a safe access to all ports of the kingdom of Scotland with their merchandise, because the kingdom of Scotland, thanks be to God, is recovered by war from the power of the English. Farewell.
>
> [Given at Badsington [Haddington] in Scotland, 11th October 1297]

The overland route between the Baltic and the North Sea was, however, gradually superseded by a direct searoute through the Danish Sound. Furthermore, the development of Bruges and later Antwerp as major trading centres in the 16th century, led eventually to the demise of Lübeck and the Hanseatic League in general. In contrast to Lübeck, however, Hamburg continued to prosper mainly as a result of the city's advantageous geographical situation. With direct access to the North Sea and the Atlantic Ocean, the city merchants were able to sail the relatively new trade routes to the East Indies.

The Hamburg authorities pursued a policy of neutrality beneficial to their own trade, and made frequent loans of large sums of money to countries such as Denmark and Sweden, who were interested in Hamburg as an open commercial market. In 1510 the city proclaimed itself an Imperial Free city or *Reichsstadt*, subject to no authority except that of the Holy Roman Emperor. Further, by the Great Recess of February 19th, 1529 the city council (*Rat*) was put in control of the city's affairs. Hamburg had its own postal service, and as early as 1558, following the model of Antwerp, had its own stock exchange. A new, larger town hall was built

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[2] W. C. Dickinson, G. Donaldson & I. A. Milne, eds., *A Source Book of Scottish History* (London: Thomas Nelson and Sons Ltd, 1958), p.136.

on the Ness, and the Bank of Hamburg was founded in 1619. The foresight of the council led to the fortification of the city in the period 1616-25 and even the employment of an army to protect it in 1618. Consequently, the city could pursue its business untroubled throughout the worst crises of the Thirty Years War (1618-1648).

It has been estimated that in the areas most severely affected by the Thirty Years War, 60 to 70 percent of the population died through battle, murder and starvation. For example in the Silesian town of Löwenberg only 40 of the 6,500 people survived.[3] With the decline in population, the demand for agrarian products diminished and there was widespread poverty in the countryside. This in turn led to a collapse of rural and urban crafts. The population of such major cities as Frankfurt stagnated, whilst in the worst affected areas, including Mecklenburg, Bavaria and parts of Westphalia it took nearly one hundred years for the communities to recover.

In contrast to many other cities, Hamburg and the surrounding countryside of Schleswig-Holstein were spared the ravages of war. Consequently the demand for craftmanship and artistic creativity was not disrupted. However, the rise of Sweden to the status of a great power towards the end of the seventeenth centry was a significant threat to the security of Hamburg. By the Treaty of Westphalia (1648) which finally ended the Thirty Years War, Sweden acquired the duchies of Bremen and Verden on the west bank of the Elbe. Although this enabled Hamburg to play Sweden off against Denmark, a country who also pressed hard on Hamburg's freedom, the threat to the city's independence was considerable. Swedish influence in the Baltic was not finally limited until Sweden's defeat by Russia in the Great Northern War (1700-21).[4] Hamburg's situation was further improved when, after

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3 R. Vierhaus, *Germany in the Age of Absolutism*, trans. J. Knudsen (Cambridge: Cambridge University Press, 1988), p.3.

1714 and concerned for free access to the Rivers Weser and Elbe, England supported Hamburg's anti-Swedish and anti-Danish policy.[5] There were also serious domestic problems which beset the city council.

Dissent from 1665 onwards by the poorer burgher families over the limited franchise in Hamburg culminated in an armed attack on the city council in 1698. The riots left several members of the council dead, and the city without a governing body for a period of some eleven years until a new constitution was drawn up in 1709.[6] Despite several years of civil unrest, it would seem that artistic creativity was not particularly disrupted, as several instruments by the celebrated Hamburg luthier Joachim Tielke (1641-1719) date from this period.

From 1710 onwards, the economic climate in Hamburg favoured the rapid development of arts and crafts. Wealthy English, Dutch, Jewish and Spanish merchants emigrated to Hamburg often to escape persecution, and, as a result, Hamburg became the focus of their already-established international commerce, and many foreigners later contributed to the wealth of the city. Indeed, one eighth of Hamburg's mayors from the time of the Reformation to the mid-nineteenth century were immigrants. Mainly as a result of this immigration, the population of Hamburg, which amounted to some 70,000 at the beginning of the eighteenth century, was the largest in the German-speaking countries after Cologne. The most important trading areas for Hamburg shipping during the working lifetime of Hieronymus and Johann Hass (approximately 1720-1770) were the North Sea, the Baltic, the Atlantic Ocean and the Bay of Biscay.

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4 After an initial setback at the battle of Narva (1708), Peter the Great visited the west and created a new Russian army which defeated the Swedes at the battle of Poltava (1709).

5 In 1714, the Elector of Hanover became George I of England.

6 B.C. Cannon, *Johann Mattheson* (New Haven: Yale University Press, 1947), p.7.

**The artistic climate in seventeenth- and eighteenth-century Hamburg**

Hamburg's wealth created an atmosphere congenial to musician and instrument maker alike. As in many other cities, the early focus of musical activity was the church. Hamburg, as with all the North German-speaking port towns, confessed to Lutheran Protestantism. In the seventeenth century, the city, divided into five main parishes (those of the Jacobikirche, Petrikirche, Catharinenkirche, Michaeliskirche and the Nicolaikirche) was the most important centre of North-German organ music. The tradition of excellence in organ playing was established in the city by Heinrich Scheidemann (circa 1595-1663) and Jacob Praetorius (1586-1651), and continued by Johann Reincken (1623-1722). One of the greatest organ builders of his day, Arp Schnitger (1648-1719), built more than twenty organs in the Hamburg area alone, including those for the Nicolaikirche in 1682 and the Jacobikirche between 1689 and 1693.[7]

Decisions concerning the well-being and development of music in Hamburg churches were not taken solely by religious authorities. The cantor of the Johanneum in Hamburg, like that of the Thomaskirche in Leipzig, was appointed by the City Council. Furthermore, the instrumentalists employed by Telemann (as *Musikdirektor* of all five parish churches from 1721 to 1767) for the performance of his weekly cantatas, were the eight town musicians assisted by the fifteen *Roll-Brüder*.[8]

The large numbers of middle-class bankers and merchants living in the city produced an atmosphere congenial to a healthy concert life. As with Lübeck, there

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[7] The organ at the Jacobikirche, built with four manuals and sixty stops, was fully restored by Jürgen Ahrend in 1993.

[8] The term was derived from the practice of entering the names of the musicians on a roster or *Rolle*.

was a tradition of regular organ concerts in Hamburg, and there are also records of performances of small sacred concertos or sonatas by the violinist Johann Schop (died 1667) and the organist Heinrich Scheidemann in the Catharinenkirche.[9] Public concerts were started in Hamburg by the organist of the Jacobikirche, Matthias Weckmann, under whose direction the Collegium Musicum (founded by Weckmann in 1660) performed in the vestibule of the cathedral. Aware that concerts could be an important source of income, Georg Telemann continued the concert tradition in Hamburg, and performed his festival cantatas in the Drillhaus (a hall originally built for the use of the city's militia) after the church service for which they had been written.[10]

Other important musical events in the city included the annual official banquets by the various civic and military bodies, such as those given by the officers of the Hamburg militia and the Town Council.[11] It is likely that it was for these banquets that Telemann wrote his *Kapitänsmusik* and *Tafelmusik*. The first opera house outside Italy was founded in 1678 at the Gänsemarkt[12] in Hamburg by councillor Gerhard Schott and the musicians Strungk, Franck, Theile and Reincken. The first opera presented was the story of Adam and Eve under the title *Der erschaffene, gefallene und aufgerichtete Mensch* (The Creation, Fall and Redemption of Man) with music by Heinrich Schütz's pupil, Johann Theile. Later, operas of a more

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9 A. Edler, "Organ Music Within the Social Structure of North German Cities in the Seventeenth Century," in *Church, Stage and Studio: Music and its context in seventeenth century Germany*, ed. P. Walker (Michigan: Ann Arbor, 1990), p.32.

10 An engraving of a *Festmahl* or celebration banquet of 1719 in the Drillhaus by Christian Fritzsch, is in the Hamburg Staatsarchiv. It is reproduced in *The New Grove Dictionary of Music and Musicians*, ed. S. Sadie, vol.8 (London: MacMillan, 1980), p.66.

11 R. Petzoldt, *Georg Philipp Telemann*, trans. H. Fitzpatrick (London: E. Benn, 1974), p.55.

12 It was here in the Gänsemarkt that the famous duel is said to have taken place between Handel and Mattheson.

secular nature were performed, the texts of which were drawn mainly from Greek and Roman history. Johann Franck's *Andromeda und Perseus* was, for example, performed in the city in 1679. Unfortunately, the opera house suffered a decline in popularity after 1725 and eventually closed in 1738. The Gänsemarkt continued its musical connection, however, since at least two stringed-keyboard instrument makers, Johann Gerlach and Christian Zell, are known to have lived there.

Amateur music-making also flourished in Hamburg in the eighteenth century. The publication of trio sonatas in Hamburg may have been intended to partly meet this demand. Buxtehude's sonatas for violin, viola da gamba and harpsichord were, for instance, published in Hamburg by Nicolaus Spieringk as opus 1 and opus 2, probably in 1694 and 1696 respectively.[13] Similarly, Telemann in 1728 brought out *Der getreue Musik-Meister* (*The Faithful Music Master*), a musical newspaper which offered new instrumental pieces and songs to musically-minded individuals on a subscription basis. An examination of the subscription list to Telemann's *Tafelmusik*, published in Paris in 1733, probably gives a good indication of the type of person willing to patronise music in Hamburg. From an examination of the list, most of the subscribers appear to have been either diplomats or aristocrats. Among the two hundred subscribers were:[14]

- Mr. de Wich, Envoyé extraordinaire de Sa Majesté Britannique.
- Mrs. les ordinaires de la Musique d'Hambourg. [the city waits]
- Mr. Mauritius, Ministre de L.H.P Messieurs les Etats Genereaux d'Hollande.
- S.E. Mr le Baron de Keurlzrock. Resident de Sa Majesté Imperiale.

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13 K. Snyder, *Dietrich Buxtehude* (London: MacMillan, 1987), p.120.

14 See the preface to G.P Telemann, *Georg Philipp Telemann Musikalische Werke*, ed. J.P. Hinnenthal (Basel: Bärenreiter Kassel, 1963), vol.XIV, *Tafelmusik Teil III*.

For all these musical activities musical instruments were a pre-requisite. With such widespread cultivation of music in Hamburg, the city could sustain musical instrument makers of the highest order such as Joachim Tielke, Johann Fleischer and Hieronymus and Johann Hass. Between about 1668 and 1796 at least sixteen stringed-keyboard instrument builders are known to have been active in Hamburg.[15] Unfortunately, due to the devastation of the city during the Second World War, and more recently the floods of the early 1960's, much archive material has been lost, and as a consequence very little biographical detail is known about Hamburg keyboard-instrument makers. Basic details of a maker such as the date of becoming a burgher can, however, be supplemented by information gleaned from surviving instruments since Hamburg makers tended both to sign and date their work. The most helpful source concerning biographical details of Hamburg musicians, composers and instrument makers is the unpublished typescript *Hamburger Tonkünstler-Lexicon.*[16]

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[15] See D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.198.

[16] K-E. Schulze & H. Richter, "Hamburger Tonkünstler-Lexicon," photocopied (Hamburg: State Library, Reading Room, 1983).

## THE HASS FAMILY AND OTHER MEMBERS OF THE HAMBURG SCHOOL

### Johann (Hans) Christoph Fleischer I (1638-ca.1690)

The name Fleischer is the German occupational name for a butcher. The instrument-maker Johann Fleischer I was baptised on 28 May 1638 in the Petrikirche, Hamburg as the son of Christoffer Fleischer, and became a burgher or citizen on 12 April 1672.[17] He married Sophia Margaretha Zaego in 1675, who, following the death of her husband in the early 1690's, later married the instrument maker Johann Middelburg. Johann Fleischer's brother-in-law, Joachim Tielke, was god-father to several of Fleischer's children. None of his instruments is known to survive. However two of his sons, Johann Fleischer II and Carl Conrad Fleischer were both keyboard-instrument makers and a small sample of their work survives.

### Johann Christoph Fleischer II (1676-ca.1730)

The eldest son of Johann Fleischer I, Johann Fleischer II was born in 1676 and received Hamburg citizenship on 12 June 1705.[18] According to the entry in Gerber's Lexicon:[19]

| | |
|---|---|
| Fleischer (Johann Christoph) ein Tasten-Instrumentmacher zu Hamburg, war ums J.1718 wegen seiner kunstkenntnisse und seiner | Fleischer (Johann Christoph) a keyboard instrument maker from Hamburg, was widely famed around 1718 because of his |

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[17] D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.43.

[18] D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), pp.43-4.

[19] E. L. Gerber, *Neues historisch-biographisches Lexicon des Tonkünstler*, 2 vols. (Leipzig: Kühnel, 1812), 2:col.144. Translated with the help of Dr. Marte Cowell.

besondern Geschitlichteit weit und breit berühmt, indem man Flügel von allerlei Art für 60, 70, 100 ja 1000 Thaler ben ihm haben konnte. Besonders aber machte ihm die Erfindung eines sogenannten Theorben-Flügels von 16 fuβ Ton, mit 3 Registern, deren 2 aus Darmsaiten und das dritte aus Drathsaiten bestand, viel Ehre. Wertwürdig, aber auch nothwendig daneben war, daβ die Darmsaiten, wie er versicherte eben so fest Stimmung und Temperatur halten sollten, als die Metallsaiten. Auch verfertigte er Lauten Clavecins von 8 fuβ Ton, welche nur 2 chörig mit Darmsaiten bezogen waren.

artistic knowledge and especially because of his deftness, for one could obtain harpsichords of all sorts from him, for 60, 70, 100 and even 1,000 thaler. The invention of the so-called 'theorbo harpsichord' at 16ft pitch with three registers, of which two had gut and the third metal strings brought him special honour. Worthy of note, but also necessary, as he stated, was the fact that the gut strings held their tuning and temperament just as well as the metal strings. He also made lute harpsichords at 8ft pitch, of which there were only two choirs of gut strings.

**Carl Conrad Fleischer (1680-ca. 1722)**

The instrument-maker Carl Fleischer was baptised on 13 November 1680 as the son of Johann Fleischer I. He had died by 1722 since in that year his widow, Florentina Fleischer, married Christian Zell.[20]

**Johann Middelburg (born ca.1670)**

The organ and clavichord builder Johann Middelburg received Hamburg citizenship on 15 January 1692. By 23 August 1694 he was married to Sophia Fleischer, the widow of Johann Fleischer I.[21] Whether this meant that he took over the workshop of Johann Fleischer I is not known. Certainly, a number of keyboard instrument makers are known to have married their master's widow. For example, Jacob Kirkman married Tabel's widow and Pascal Taskin married Blanchet's widow. There are no known surving instruments by Middelburg.

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20 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.44.

21 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.113.

**Christian Zell (born ca. 1700)**

The name Zell is possibly derived from the German word *Zelle*, a small room. It may have been an occupational name for someone who owned or was employed in a small workshop, or it may be a habitation name from the town of Celle near Hannover.[22] Christian Zell acquired Hamburg citizenship on 14 August 1722. A few weeks later, on 1 September 1722, he married Florentina Fleischer, the widow of Carl Conrad Fleischer, and took over Fleischer's workshop.[23] Among the god-parents at his children's baptisms was the lute-maker Gabriel Tielke. Zell is known to have lived at the Gänsemarkt.

**Hieronymus Albrecht Hass (1689-ca.1745)**

The name Hass itself is a German nickname for a bitter and vicious man, derived from the German word *Hass*, meaning hatred[24]. Few details concerning the life of the harpsichord and clavichord builder Hieronymus Hass are known. He was baptised as the son of Conrad Hass at the Jacobikirche in Hamburg on 1 December 1689. Hieronymus Hass married Margreta Dorotea von Höffen on 12 October 1711 and became a burgher on 23 March 1714. According to Raymond Russell's correspondence from a Dr Schmidt of the Hamburg Staatsarchiv[25] this had followed the payment of 40 Marks in four yearly instalments from 1711. According to Schmidt, the reason for the high fee was that his father was not a burgher, so Hieronymus had to pay an initial fee as well. In Hamburg, to be a burgher at this time imposed a variety of duties, such as to bear arms and to contribute to the maintenance of

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22 P. Hanks & F. Hodges, *A Dictionary of Surnames* (Oxford: Oxford University Press, 1988), p.593.

23 M-A. Dittrich, *Musikstädte der welt Hamburg* (Hamburg: Laaber, 1990), p.49.

24 P. Hanks & F. Hodges, *A Dictionary of Surnames* (Oxford: Oxford University Press, 1988), p.243.

25 The correspondence in the Russell Collection, University of Edinburgh, is dated 30th October, 1952.

hospitals, almshouses and orphanages and so Hass would have had to help in the event of an armed attack on the city. From 1715 Hass lived in the Rackerstrasse. His surviving instruments range in date from 1721 to 1744. As well as the extant instruments he is known to have made at least two others: the Museum für Hamburgische Geschichte in Hamburg is thought to have owned a Hass clavichord at the end of the nineteenth century dated 1736, while in 1744, Hass is known to have supplied a 'clavicymbel' to the Duke Friedrich Carl von Plön (1706-1761).[26] Although Hass's date of death is not known for certain it was presumably about 1745. There are no known instruments signed by both Hieronymus and Johann Hass. According to the entry under 'Hass' in Gerber's Lexicon of 1790:[27]

| | |
|---|---|
| Hasse, Vater und Sohn beydes Orgelmacher zu Hamburg, auch beyde nicht mehr am Leben; machten vortreffliche Flügel und Klaviere, die noch sehr gesucht werden. | Hasse, father and son both organ makers of Hamburg, both are no longer living; they made splendid harpsichords and clavichords, which have come to be very much sought after. |

By 1790, the word *flügel* may have meant piano. However, since there is no indication that Hass made pianos, the word has been translated as *harpsichord*. A little more detail is given in the 1812 edition of Gerber,[28] which states "lebten beyde schon im J. 1773 nicht mehr" (both no longer living in 1773).

**Johann Adolph Hass (born ca. 1720-25, died ca. 1773)**

The son of Hieronymus Hass, Johann received Hamburg citizenship on 28 October 1746 by virtue of being the son of a burgher. His year of birth is not

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26 A. Pilipczuk, "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (September 1988), p.46.

27 E. L. Gerber, *Historisch-biographisches Lexicon des Tonkünstler*, 2 vols. (Leipzig: Breitkopf, 1790), 1:col.590.

28 E. L. Gerber, *Neues historisch-biographisches Lexicon des Tonkünstler*, 2 vols. (Leipzig: Kühnel, 1812), 2:col.519.

recorded. In the same year as becoming a burgher, Johann Hass married Anna Elizabeth Tramnitz (baptised 3 August 1724), the daughter of a grocer, on 22 November 1746 at the Catharinenkirche.[29] Between 1756 until at least 1761 he was living on the Jungfernstieg, originally built as a dam to confine the waters of the Alster, and only a short distance from the Gänsemarkt. One of their daughters, Margaretha Catharina Hass (baptised 4 November, 1754) married the instrument-maker Johann Christoph Krogmann on 4 November 1754. According to Gerber, Johann Hass was dead by 1773; he probably died sometime between about 1770 and 1773.

It should be noted that there is no known family connection between Johann Adolph Hass the instrument maker, and the composer of the same name.[30]

**Johann Christoffer Krogmann (1748-1816)**

The name Krogmann is a metonymic variant of the name Krüger, a North-German occupational name for a tavern keeper, or maker or seller of mugs, jugs and pitchers; from the German word *Krug*, a jug or a pitcher.[31] The Hamburg instrument-maker Johann Krogmann was baptised the son of the bookbinder Hans Diederich Krogmann on February 14th, 1748 in the Catharinenkirche in Hamburg. He became a burgher on October 13th, 1780 and a year later married into the Hass family. Three years later, in 1784, he was living on the Dreckwall. There is only

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29 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.61.

30 The composer and teacher of Glück, Johann Adolph Hass, was born at Bergedorf near Hamburg and was baptized on 25 March 1699. He died in Venice on 16 December, 1783.

31 P. Hanks & F. Hodges, *A Dictionary of Surnames* (Oxford: Oxford University Press, 1988), p.308.

one known surviving keyboard instrument by Krogmann, the square piano at the Museum für Kunst und Gewerbe in Hamburg.[32]

**Johann Christian Gerlach (ca. 1720-ca. 1795)**

The name Gerlach is derived from the German adjective *geläufig*, meaning common or familiar.[33] Johann Gerlach became a citizen of Hamburg in 1744, and by 1746 was living in the Gänsemarkt. In the same year, Gerlach married Anna Margaretha, the daughter of Conrad Hinrich Wulff. Although only three of his clavichords are known to survive Gerlach is also thought to have made harpsichords. According to Dr Gisella Jaacks (of the Museum für Hamburgische Geschichte in Hamburg) he supplied harpsichords to all the nobility in Holstein.[34] The many similarities between the surviving clavichords of Hass and Gerlach, first pointed out by Grant O'Brien,[35] suggest some sort of working relationship between the two. Either he must have been apprenticed to Hieronymus Hass or he worked in the same workshop as Johann Hass. The eighteenth-century lexicographer Ernst Gerber (1746-1819),[36] wrote that Gerlach's "Flügel und Klaviere besonders geschätz werden" (harpsichords and clavichords are particularly treasured).

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32 The square piano, inv. no. 1904.712, signed 'Johann Christoph Krogmann / Hamburg Anno 1784' has a five octave compass of FF-$f^3$. The case measures 1507mm long by 486mm wide (1521mm and 499mm inclusive of the mouldings respectively). The case sides are made from mahogany.

33 J. Brechenmacher, *Deutsche Sippennamen*, 2 vols. (Görlitz: C.A Starke, 1936), 1:col.204.

34 Personal correspondence with Dr Jaacks of the Museum für Hamburgische Geschichte, Hamburg.

35 G. O'Brien, "Catalogue Description of the 1756 I.C. Gerlach Clavichord," held at Ringve Museum, Trondheim, with copies at the Russell Collection (Edinburgh, 1990), p.33. The similarities are discussed on pp.238-47 of the present work.

36 E. L. Gerber, *Historisch-biographisches Lexicon des Tonkünstler*, 2 vols. (Leipzig: Breitkopf, 1790), 1:col.500.

The entry for Gerlach in Fétis[37] gives some extra details:

> Gerlach: facteur de pianos et de clavecins, était établi à Hambourg, en 1790; ses instruments étaient éstimes. Son fils, pianiste et compositeur, a vécu à Copenhague pendant plus de vingt ans. Il a publié quelques petites pièces pour le piano, des danses et des polonaises pour le violon.

> Gerlach: maker of pianos and harpsichords, was working in Hamburg in 1790; his instruments were highly valued. His son, pianist and composer, lived in Copenhagen for more than twenty years. He published several short pieces for the piano, some dances and some Polonaises for the violin.

**Dietrich Christoph Hass (ca.1731-ca.1796)**

Dietrich Hass, the third son of Christian Hass III, was baptised in the Petrikirche in Hamburg on 3 October 1731. The family is not thought to be have been related to Hieronymus and Johann Hass. The clavichord in the Museum für Kunst und Gewerbe, Hamburg, signed 'Dietr. Chr. Hass Hamburg 1796' (inv. nr. 1904.709) is the only known surviving instrument by this maker.

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37 F-J. Fétis, *Biographie Universelle Des Musiciens et Bibliographie Générale de la Musique*, 8 vols. (Paris: Didot Frères, 1860-65), 3:459.

# Chapter 2

## THE EARLY CLAVICHORD AND THE EARLY HAMBURG SCHOOL OF INSTRUMENT MAKING

### INTRODUCTION

The clavichord belongs to the chordophone class of instruments as defined by Hornbostel and Sachs; that is to say the sound is produced from strings which are under tension.[1] The clavichord is usually a rectangular-shaped keyboard instrument in which the strings are set in motion by brass blades known as tangents fixed towards the tail end of the keylevers. The keylevers are pivoted on balance pins, and guided by tongues of wood, metal or whalebone set in the tail ends of the levers which ride in the vertical slots of a rack. On the depression of a keylever its tail end rises and the tangent strikes its pair of strings. As the tangent remains in contact with the strings as long as the key is depressed it performs a dual function: it sets the strings in motion and also determines the vibrating string length. This contact with the strings enables the player to have subtle control over the sound, as well as to produce a vibrato effect known as 'bebung', by varied pressure of the key head. However, the tangent prevents the striking point from vibrating freely, thus forming a point of high impedance, and some of the string's vibrational energy is also absorbed by the tangent and ultimately the player's finger. A minimal amount of energy is thus able to be transferred transversely along the length of the string from the tangent impact point to the bridge and soundboard, with the result that the clavichord is an inherently quiet-sounding instrument.

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1 E. von Hornbostel & C. Sachs, "Systematik der Musikinstrumente: ein Versuch," *Zeitschrift für Ethnologie*, XLVI (1914), pp.553-90; A. Baines & K.P. Wachsmann, "Classification of Musical Instruments," *The Galpin Society Journal*, XIV (1961), pp.3-29.

## THE ORIGINS AND EARLY HISTORY OF THE CLAVICHORD

The origins of the clavichord are difficult to unravel. There are no known surviving examples from the Medieval period and contemporary nomenclature during this period is often ambiguous; words like 'clavichord', 'clavicordium', 'monochord', 'eschacherio' and 'chekker' did not have any standardised definition at this time and were sometimes even interchangeable. In Spanish terminology, for instance, Beryl Kenyon has pointed out that the word 'clavicordio' has been used as a generic term for a keyboard instrument, which in different contexts can mean either harpsichord, virginal, or clavichord.[2]

The chekker (*eschiquier*, *exaquier* or *Schachtbrett*) is mentioned in writings from the fourteenth to the sixteenth century. These include the account books of King John the Good of France (1360), letters of King John I of Aragon (1388) and the writings of Johannes Gerson (1424).[3] Several writers have attempted to identify the instrument: Curt Sachs, for example, suggested that the chekker was a type of upright harpsichord known as a clavicytherium.[4] The chekker may, however, have received its name from a resemblance to the medieval counting-board, an exchequer, which would seem to indicate that that the instrument was rectangular rather than wing-shaped. Both Edwin Ripin[5] and Nicolas Meeùs[6] have provided good argu-

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[2] B. Kenyon de Pascual, "Two Features of Early Spanish Keyboard Instruments," *The Galpin Society Journal*, XLIV (1991), p.94.

[3] See the appendix to E.M. Ripin, "Towards an Identification of the Chekker," *The Galpin Society Journal*, XXVIII (1975), p.15-23.

[4] C. Sachs, *The History of Musical Instruments* (New York: Norton, 1940), pp.336-7.

[5] E.M. Ripin, "Towards an Identification of the Chekker," *The Galpin Society Journal*, XXVIII (1975), pp.11-25.

ments that the term chekker was synonymous with the term clavichord. Their main evidence is the entry in the French Royal Account Book for 1488, for the payment of 36 livres 'for a chekker or clavichord'.[7] Further indication that the chekker was in fact the early name for the clavichord is provided by the writings of the French theologian Johannes de Gerson (1363-1429); in his treatise *Tractatus primus de canticorum originali ratione* (Amsterdam, 1706) Gerson distinguishes instruments like the lute, cittern and chekker from the harp and psaltery.[8] Since both the harp and psaltery are provided with a string for each note, whereas the lute and cittern are able to produce a series of notes from each string, the chekker by association would also appear to be a fretted instrument. All the existing evidence seems to indicate that the term chekker was in fact the early name for the clavichord until the early years of the fifteenth century. The earliest known appearance of the term clavichord is thought to be a reference in Eberhard Cersne's rules for the Minnesingers, *Minne Regal* (1404).[9]

The early clavichord or chekker is generally thought to have been conceived as an elaborate monochord, an instrument usually attributed to Pythagoras around 550 BC, and consisting of a single string stretched between two bridges. The common musical intervals of an octave, fifth and fourth are produced by dividing the string into two proportional sections with a moveable bridge. The early clavichord can be thought of as several monochords placed side-by-side as the instrument had just

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[6] N. Meeùs, "The Chekker," *The Organ Yearbook*, XVI (1985), pp.5-25.

[7] The extract from Paris, Archives Nationales, KK 70, fol. 324v is translated as appendix no. 25; in E. Ripin, "Towards an Identification of the Chekker," *The Galpin Society Journal*, XXVIII (1975), p.21.

[8] See E.M. Ripin, "Towards an Identification of the Chekker," *The Galpin Society Journal*, XXVIII (1975), pp.11-25.

[9] E.M. Ripin, "Towards an Identification of the Chekker," *The Galpin Society Journal*, XXVIII (1975), pp.17-8.

four or five strings of equal length and all tuned to the same note from which to produce a multiplicity of pitches. The moveable bridge of the monochord was replaced by keys fitted with tangents towards their tail end. The positioning of the key tails was pre-determined so that on depression of the keylever the tangent automatically determined the correct string length in order to produce the desired pitch.

As the theory of music remained Pythagorean until the fourteenth century it is possible that the tangents of early clavichords were positioned according to Pythagorean principles. Tangents for two notes an octave apart may, for example, have been positioned to determine string lengths in the ratio 2:1, while tangents for two notes a fifth or a fourth apart may have been positioned to determine string lengths in the ratio 3:2 and 4:3 respectively. Many seventeenth- and eighteenth-century keyboard instruments have string lengths that halve and double for each octave rise and fall in the treble part of the compass, but one cannot be certain if this was the case for fourteeth- and fifteenth-century instruments. The spacing between fretted keys is always defined by the ratio of the interval, but there is no such limitation between unfretted notes unless one wants the strings to be tuned in unison.

With only a few strings from which to produce some twenty or thirty different pitches there had to be two, three or even four tangents per course of strings. This principle is known as fretting. Since the tangent remains in contact with the strings as long as the key is depressed only one note can be produced from a single course at any one time. If an attempt is made to play two notes which require the same course simultaneously the upper of the two notes sounds since in effect its tangent is stopping the vibrating string as defined by the lower tangent. The lower tangent, because of its proximity to the tangent being played, restricts the amount of vibration of the higher note. It is possible that the maker, once he had determined the total number of strings, tried to minimize the inconvenience of fretted notes to the player. Clavichord makers (of the seventeenth and eighteenth centuries) were, for example, careful not to include two notes on the same course which made up an interval of a major or minor third.

Both the volume and tone quality of a clavichord are very much dependent upon the characteristics of the strings. In general, although a thick, heavy string can be struck more forcefully and radiate more sound energy than a thin one, it is also stiffer and has a greater enharmonicity or sharpness factor. That is to say the harmonics of a thick string are more out-of-tune than those of a thin string. The historical clavichord builder's solution to the problem of increasing the motion of the bridge without jeopardising the flexibility of the strings was to provide two thin strings rather than one thick string for each note. If two strings vibrate with the same frequency, phase and amplitude the motion of the bridge is double that if only one string was vibrating, a principle known as constructive interference.

Quite a number of fifteenth-century representations of clavichord-like instruments have been documented,[10] the earliest of which (dating from 1425) is part of the altarpiece from the Cathedral at Minden, and presently preserved at the Bodemuseum, Berlin.[11] A manuscript treatise[12] of some fifteen years later, by the French physician and astronomer Henri Arnault de Zwolle (circa 1400-1466) gives a detailed description as well as a diagram of an early clavichord.[13] A fascinating

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[10] See E. Bowles, "A Checklist of Fifteenth-Century Representations of Stringed Keyboard Instruments," in *Keyboard Instruments*, ed. E.M. Ripin (Edinburgh: Edinburgh University Press, 1971), pp.11-6 and plates 1-31.

[11] See H. Heyde, "Die Musikinstrumentendarstellung auf dem Mindener Altar," *Beiträge für Musikwissenschaft*, VI (1964), pp.32-3.

[12] Bibl. Nat., Paris, MS latin 7295, published in facsimile, with a French translation by G. Le Cerf & E. Labande as *Instruments de musique du XV siècle. Les traités d'Henri-Arnaut de Zwolle et de divers anonymes* (Paris, 1932).

feature of this instrument, which has nine or ten pairs of equal-length strings running parallel to the spine, is that the ratio of the length of the case to its width is 14:3.[14] The keyboard projects outside the rectangular-shaped body, and has the three-octave compass B to $b^2$, the note-letter names of which are written on the touch plates. The clavichord is fretted throughout the compass, with up to four tangents striking the same course of strings.

Arguably the best representation of a fifteenth-century clavichord is that which is part of the intarsia, made about 1479-82, at the ducal palace at Urbino, Italy.[15] Perhaps the most significant feature of this representation is that the compass appears to be F,G,A to $f^3$, forty-seven notes. This extension of the compass beyond three octaves was achieved by increasing the number of courses to seventeen and providing the bottom five notes, F, G, A, B flat and B with their own course of strings. By increasing the number of courses, the cranking of the bass keys (where, if there is fretting, the distance between two consecutive tangents needs to be larger than that necessary in the treble) can be reduced to a minimum. All known clavichords have separate courses for the bass notes for this reason. The instrument displays both triple and quadruple fretting from the note b upwards, with no group of four tangents encompassing a consonant interval except for the highest group, $d^3$, $e^{b3}$, $e^3$ and $f^3$. As a result of this, diatonic intervals can be played homophonically

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13 Illustrated in N. Meeùs, "The Chekker," *The Organ Yearbook*, XVI (1985), pp.18-9.

14 D. Wraight, "The identification and authentification of Italian string keyboard instruments," in *The Historical Harpsichord*, ed. H. Schott, 3 vols. (Stuyvesant, New York: Pendragon Press, 1992), 3:68.

15 For an illustration, see E.M. Ripin, "The Clavichord," in *Early Keyboard Instruments*, The New Grove Musical Instrument Series, ed. S. Sadie (London: MacMillan, 1989), p.146.

throughout most of the compass, except for the top four notes which can only be played melodically.

An early sixteenth-century illustration of a fretted clavichord occurs in Sebastian Virdung's treatise, dedicated to the Bishop of Strasbourg, *Musica getutscht* (Basle, 1511).[16] Unfortunately, only a limited amount of information can be gleaned from the woodcut. The instrument labelled 'Clavicordium', has just seven strings of equal length stretched across the entire length of the instrument and according to Virdung these are all tuned in unison. The clavichord illustrated has twenty-three naturals and fifteen accidentals, which gives the apparent compass A to $a^2$,$b^2$. The woodcut is, however, rather crude and shows none of the playing mechanism of the instrument. Furthermore, two other illustrations, labelled 'Virginal' and 'Clavicimbalum', cast some doubt on the correctness of orientation of the clavichord. Since the virginal and clavicimbalum appear to be mirror-images, some writers have suggested that the engraver failed to reverse the image on the 'Clavicimbalum' printing block. If the blocks were made by a musically illiterate engraver, are the images correctly oriented? Some writers have thought that the engraver made a mistake and suggested that the real compass may have been F,G to $g^2$. It is, however, a fundamental technique of engraving to reverse the image, and it was not until the nineteenth century that organologists started to find fault with the orientation of the engravings. Virdung and other contemporary writers apparently did not find anything wrong with the illustrations. Indeed, Eisenberg has suggested that the orientation of the instrument is correct and that the instrument was tuned in accordance with Ancient Greek practices whose note letter names were read downwards as A, G, F, E, D, C, B, A.[17] Schuman has published a list of nearly three dozen works of art in which are represented 'reversed organs'.[18] Schuman's explanation for il-

[16] For further discussion see J. Eisenberg, "Virdung's Keyboard Illustrations," *The Galpin Society Journal*, XV (1962), pp.82-8.

lustrations of organs with the bass pipes on the right descending to small treble pipes on the left is that keyboard instruments, like wind instruments, may have been made for left-handed players. In fact there may not have been a standard way of left- or right-hand instruments at this time.

The 1543 Domenicus Pisaurensis clavichord[19] in the Grassi Museum, Leipzig[20] is the oldest surviving dated clavichord. It is a polygonal instrument with a projecting keyboard and relatively thin case sides of cypress which overlap the baseboard. The case measures 1227mm long by 265mm wide and 152mm high, without the thickness of the mouldings. The strings, which run parallel to and the full length of the spine, are stretched across three straight bridges. Rather than using bridge pins, Pisaurensis used a small length of brass wire which runs along the top of each bridge. Consequently, there is no sidedraft to keep the strings from being lifted off the bridge when a key head is depressed. To prevent the strings from rising off the bridge, Pisaurensis effected a slight but sufficient downdraft by angling the extreme right-hand end of the soundboard downwards towards the tuning pins. As well as the soundboard situated in the right-hand end of the case, there is also an extra board positioned beneath the keylevers known in German as a *Klaviaturresonanzboden*.[21] There are twenty-two pairs of strings for the forty-five

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17 J. Eisenberg, "Virdung's Keyboard Illustrations," *The Galpin Society Journal*, XV (1962), p.83.

18 J. Schuman, "Reversed Portatives and Positives in Early Art," *The Galpin Society Journal*, XXIV (1971), pp.16-21.

19 See H. Henkel, *Clavichorde, Musikinstrumenten-Museum der Karl-Marx Universität, Katalog, Band 4* (Leipzig: VEB Deutscher Verlag für Musik, 1981), Cat. No.1, pp.21-3; illustration plate 1.

20 The Museum was previously known as the Musikinstrumenten-Museum der Karl Marx Universität, Leipzig.

note compass, C/E to $c^3$. The bottom eleven notes C to d are unfretted, the rest fretted in twos, threes and fours as follows:

$e^b$-e, f-f#, g-g#-a, $b^b$-b-$c^1$-$c^{\#1}$, $d^1$-$e^{b1}$-$e^1$, $f^1$-$f^{\#1}$-$g^1$-$g^{\#1}$, $a^1$-$b^{b1}$-$b^1$, $c^2$-$c^{\#2}$-$d^2$, $e^{b2}$-$e^2$-$f^2$-$f^{\#2}$, $g^2$-$g^{\#2}$-$a^2$, $b^{b2}$-$b^2$-$c^3$.

There are also two anonymous sixteenth-century clavichords at Leipzig which have been attributed by Hubert Henkel to either Hans Müller of Leipzig or to a maker working in the Nurenberg tradition.[22] However, following a scientific study of the moulding profiles Denzil Wraight has argued convincingly that the two instruments were probably made in the Italian city of Naples.[23] The two instruments have a number of features in common with the Pisaurensis clavichord: the thin case sides (of maple or sycamore) are built around the baseboard; the strings are stretched across several straight bridges; and there are no bridge pins. In order to hold down both the bridges and the strings, wooden bars (running parallel to and between the bridges) are positioned between the two longer case sides to exert downward pressure on the strings. Both instruments have the compass C/E to $c^3$, forty-five notes. The bottom eight notes C-B are unfretted, the rest are fretted in threes and fours as follows:

c-c#-d, $e^b$-e-f-f#, g-g#-a, $b^b$-b-$c^1$-$c^{\#1}$, $d^1$-$e^{b1}$-$e^1$, $f^1$-$f^{\#1}$-$g^1$-$g^{\#1}$, $a^1$-$b^{b1}$-$b^1$, $c^2$-$c^{\#2}$-$d^2$, $e^{b2}$-$e^2$-$f^2$-$f^{\#2}$, $g^2$-$g^{\#2}$-$a^2$, $b^{b2}$-$b^2$-$c^3$.

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21 This feature, not usually found on instruments from the seventeenth- and eighteenth-centuries, has not been fully explained. Although it is difficult to say exactly what the makers' intentions were, it is safe to say that the board performs no acoustical function.

22 See H. Henkel, *Clavichorde, Musikinstrumenten-Museum der Karl-Marx Universität, Katalog, Band 4* (Leipzig: VEB Deutscher Verlag für Musik, 1981), Cat. Nos.2 & 3, pp.23-6 and 26-8 respectively; illustrations plates 2 and 3.

23 D. Wraight, "The identification and authentification of Italian string keyboard instruments," in *The Historical Harpsichord*, ed. H. Schott, 3 vols. (Stuyvesant, New York: Pendragon Press, 1992), 3:63-75 & 137-41.

## THE SEVENTEENTH-CENTURY CLAVICHORD

### The clavichord illustrations in Praetorius's Syntagma Musicum

The most important source of information on early seventeenth-century clavichords is Volume II of Michael Praetorius's *Syntagma Musicum* (Wolfenbüttel, 1620). Although the text[24] gives only a brief account of the clavichord at that time, the engravings of three clavichords are very interesting. The illustrations, of an instrument from Italy, together with a 'usual' and an 'octave' clavichord (presumably from Germany), form part of an appendix to Volume II of *Syntagma Musicum* entitled *Sciagraphia*. The scale of Brunswick measure (1 Zolle = 23.8mm) at the top of plate XV enables both the case size and the string lengths of the clavichords to be calculated.[25] The polygonal Italian clavichord, with a projecting keyboard and the compass C/E to $f^3$, measures approximately 5 Brunswick Füsse long (nominally 1428mm). The soundboard is in the right-hand end of the instrument and there appear to be as many as four or five straight bridges. The $c^2$ scaling appears to be 14 Brunswick Zolle long (nominally 333mm). Since the clavichord was built in Italy, however, these measurements are not entirely reliable: the instrument would have been built using the local unit of measure. The fact that the case sides can be expressed as multiples of the Brunswick Zoll may indicate that the engraver used a certain amount of artistic license.

Both the usual and octave clavichord may be German in origin and as such the use of the Brunswick Zoll to determine their size is more legitimate. Both are rectangular-shaped instruments with projecting keyboards, and the case sides appear to be built onto the baseboard. The usual clavichord, with a C/E to $c^3$ compass,

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24 For a translation see M. Praetorius, *Syntagma Musicum II*, Early Music Series, vol.7, trans. & ed. D. Crookes (Oxford: Clarendon Press, 1986), pp.64-6.

25 W.R. Thomas & J.J.K. Rhodes, "A Clavichord, A Harpsichord and a Chamber Organ in the Russell Collection, Edinburgh," *The Organ Yearbook*, V (1974), p.91.

measures approximately 36 Brunswick Zolle long (nominally 1142.4mm) by 10 Zolle wide (nominally 238mm). The clavichord has two interesting features: the soundboard is situated in the left-hand end of the instrument rather than the right; and the bridge is 's'-shaped at a time when most clavichord bridges appear to have been virtually straight, or only slightly hooked in the treble. In contrast to the usual clavichord, the octave clavichord (with the compass C/E to $g^2$,$a^2$) measures only about 36 Zolle long (nominally 856.8mm) by 7 Zolle wide (nominally 166.6mm). This instrument has a single straight bridge positioned parallel to the shorter pair of case sides.

Grant O'Brien has shown that by comparing the string lengths of two instruments the relative pitch of the two can be determined.[26] Using the method put forward by O'Brien, the two Praetorius clavichords appear, in fact, not to be an octave apart in pitch. The standard $c^2$ scaling for brass strings at about A415 Hz is 285mm. Since the $c^2$ scaling for the usual clavichord (as calculated by Rhodes and Thomas[27]) is 250mm this implies brass as a suitable stringing material, but probably at a pitch about a tone higher than A415 Hz, at *Chorton* rather than *Kammerton*. Since the string scalings of the octave instrument appear to be Pythagorean, they can be represented by the $c^2$ length of 165mm. This length does imply that the instrument was designed to sound at 4ft pitch, but with iron rather than brass as a stringing material in the treble. The two instruments are therefore separated in pitch by a seventh rather than by an octave. A table of the string lengths of these two instruments is given below:

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26 G. O'Brien, *Ruckers, a harpsichord and virginal building tradition* (Cambridge: Cambridge University Press, 1990), pp.55-60.

27 W.R. Thomas & J.J.K. Rhodes, "A Clavichord, A Harpsichord and a Chamber Organ in the Russell Collection, Edinburgh," *The Organ Yearbook*, V (1974), p.90.

**Table 2.1**
**The calculated string scalings of two of the Praetorius clavichords**

| | 'Usual' Nominal (Zolle) | 'Usual' Nominal (mm) | 'Usual' Actual (mm) | | 'Octave' Nominal (Zolle) | 'Octave' Nominal (mm) | 'Octave' Actual (mm) |
|---|---|---|---|---|---|---|---|
| $c^3$ | 5 | 119.0 | 120 | $a^2$ | 4 | 95.2 | 95 |
| $c^2$ | $10\frac{1}{2}$ | 250.0 | 250 | $c^2$ | 7 | 166.6 | 165 |
| $c^1$ | $17\frac{1}{2}$ | 416.5 | 420 | $c^1$ | 14 | 333.2 | 333 |
| c | 34 | 809.2 | 810 | c | 21 | 499.8 | 500 |
| C | 42 | 999.6 | 1000 | C | 29 | 690.2 | 690 |

Mainly as a result of large numbers of unsigned and undated seventeenth- and early-eighteenth century clavichords being preserved in German Museums, most are considered to be German in origin.[28] Some do have German note names, that is B and H for B flat and B natural respectively, either written directly onto the sound-board or onto a strip of paper glued to the soundboard beside the tuning pins, but German-style note names were also used by makers from the Scandinavian countries and Flanders. In some cases, however, the survival of an inscription has helped in determining an instrument's country of origin. During the restoration of the anonymous fretted clavichord number 21, Russell Collection, University of Edinburgh, for example, the remains of an ink inscription on the upper surface of the baseboard was discovered. All that remained was part of the German word *verfertigt* (finished), thus confirming its German provenance.[29]

Despite the lack of direct evidence that many clavichords are in fact German, the countries of France, England, Spain and Portugal can in general be excluded as possible countries of origin for most small unsigned clavichords. Although French musicians and composers such as J. Lesecq (1617), Guillaume Marchand (1740) and

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[28] J.H. van der Meer, "The Dating of German Clavichords," *The Organ Yearbook*, VI (1975), pp.100-13.

[29] J. Barnes, "Restoration of German fretted clavichord c.1700," typescript (Edinburgh: University of Edinburgh, Russell Collection, 1967).

Jean Landini (1761) are all known to have owned clavichords[30] there are no known surviving signed French clavichords.[31] The reasons for this are not known. Certainly, French seventeenth-century harpsichords are very rare since, as a symbol of the aristocracy, many were confiscated during the French Revolution and later burned. In England, clavichords are among the instruments and accessories advertised for sale by the London dealer Robert Bremner at the end of a flute tutor, circa 1765.[32] The clavichord signed *Peter Hicks fecit*,[33] in the Victoria and Albert Museum, is, however, thought to be the only eighteenth-century English clavichord in existence. Some people have even doubted the authenticity of this instrument, suggesting instead that the inscription was added to a clavichord of German origin.[34]

**Spanish and Portuguese Clavichords**

The clavichord played an important rôle in the musical life of both Spain and Portugal during the seventeenth and eighteenth centuries and continued to be made long after the instrument had lost favour to the square piano in most German-speaking countries with the exception of Sweden. According to Beryl Kenyon de Pascual there may be as many as three-dozen Iberian clavichords in existence, most of which are neither signed nor dated.[35]

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30 See F. Hubbard, *Three Centuries of Harpsichord Making* (Cambridge, Massachusetts: Harvard University Press, 1967), pp.313 & 317-8.

31 F. Knights, "Some Observations on the Clavichord in France," *The Galpin Society Journal*, XLIV (1991), pp.71-6.

32 E. Halfpenny, "An Eighteenth-Century Trade List of Musical Instruments," *The Galpin Society Journal*, XVII (1964), p.99.

33 Museum number W.7-1917. See H. Schott, *Catalogue of Musical Instruments, vol.1: Keyboard Instruments* (London: Her Majesty's Stationary Office, 1985), pp.94-5.

34 R. Russell, *Catalogue of Musical Instruments, Vol.1: Keyboard Instruments* (London: Her Majesty's Stationary Office, 1968), p.56.

Although no significant research has yet distinguished clearly between Spanish and Portuguese clavichords, there do appear to be two characteristics which distinguish Iberian clavichords from those made in German-speaking lands. First, Bernard Brauchli has found that sweet chestnut (*Castanea sativa*) is used for the keylevers of most of the Portuguese clavichords in the Conservatório Nacional de Música in Lisbon.[36] In contrast, clavichords from German-speaking countries all use either poplar or lime for the keylevers because of the wood's carving potential. Since the keylevers of a clavichord are visible beneath the strings many makers carved the upper surface of the keys in a variety of different ways. The straight grain and fine even texture of both poplar (*Populus sp.*) and European lime (*Tilia vulgaris*), with little contrast between spring and summer growth, makes them ideal for carving. Second, Iberian clavichords (such as the fretted clavichord made by Jacinto Ferreira of Lisbon in 1783[37]) leave the e's and b's unfretted, whereas all known clavichords from German-speaking lands leave most of the d's and a's unfretted.

### North-European clavichords

Seventeenth- and early eighteenth-century clavichords from Northern Europe are typically small, compact instruments measuring about 100 cm long by 30 cm wide, with few pretensions. The case sides are usually made from pine or sometimes walnut, dovetailed together to form a rectangular frame. This frame is glued

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35 B. Kenyon de Pascual, "Two Features of Early Spanish Keyboard Instruments," *The Galpin Society Journal*, XLIV (1991), p.98.

36 B. Brauchli, "Comments on the Lisbon Collection of Clavichords," *The Galpin Society Journal*, XXXIII (1980), pp.98-105.

37 The instrument is preserved at the Conservatório Nacional de Música in Lisbon. Recorded in D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.43; see also B. Brauchli, "Comments on the Lisbon Collection of Clavichords," *The Galpin Society Journal*, XXXIII (1980), pp.101 & 105.

to the upper surface of the baseboard. Most clavichords of this period have the forty-five note compass C/E to $c^3$.

The anonymous fretted clavichord in the Deutsches Museum, Munich[38], which has split accidentals in all three octaves to provide both $e^b$'s and $d^\#$'s, is clear evidence that clavichords were designed for the standard temperament of the day, quarter-comma meantone. Since this tuning system is based on pure major thirds, one cannot normally play round the circle of fifths past the key of A major on the sharp side or $B^b$ major on the flat side. The split $e^b/d^\#$ accidentals on this anonymous clavichord enables the player to sound the chord of b major with a $d^\#$ as well as the chord of $e^b$ major.

All known clavichords from this period are fretted (*gebunden*), usually from the note $B^b$ or B upwards, except for the d's and a's which are free. The earliest known reference to an unfretted (*bundfrei*) clavichord is in the preface to Johann Speth's *Ars Magna Consoni et dissoni* (1693).[39] There is also a reference to an unfretted clavichord with one hundred strings in the inventory of Nicolas Gigault of 1701[40]. Assuming that Gigault's clavichord was double-strung throughout there are three possible compasses for an instrument with fifty notes, either C,D to $d^3$, GG/BB to $c^3$ or C/E to $f^3$. The earliest surviving unfretted clavichord is that made by the Hamburg maker Johann Fleischer in 1723.

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[38] Deutsches Museum, Munich, inventory number 18165.

[39] See F. Knights, "Some Observations on the Clavichord in France," *The Galpin Society Journal*, XLIV (1991), pp.71-6.

[40] F. Hubbard, *Three Centuries of Harpsichord Making* (Cambridge, Massachusetts: Harvard University Press, 1967), p.316.

Unlike the illustrations of the three clavichords in Praetorius, the extant anonymous clavichords of the seventeenth- and early eighteenth-centuries usually have an inset keyboard with the strings set obliquely to the longer of the pair of case sides. As well as enabling the bass strings to be longer, this also provides more free soundboard area around the bass end of the bridge. The length and layout of the strings is in fact paramount to the design of a clavichord, and the very best makers designed their instruments so that the string scalings in the top two to three octaves (usually based on a $c^2$ scaling of either 285mm or 250mm) are Pythagorean. Accurate Pythagorean scalings on a clavichord cannot be achieved solely by either the tangent spacing and splaying of the keys, or the shape of the bridge, but rather a combination of the two. If an entirely straight bridge is used the tangents are very tightly spaced in the treble and too widely spaced in the bass, whereas if straight keys are used, the treble end of the bridge is severely hooked and there is little space to position the bridge pins. In order to avoid making the tails of the treble keylevers so thin that they are likely to break or the bass keylevers so cranked that they are difficult to balance, either the use of Pythgorean scalings has to be dispensed with,[41] or the rack-slot spacing has to get narrower towards the treble, and the bridge has to be 's'-shaped. According to the mid eighteenth-century Saxon emigré David Tannenberg the exact curve of an 's'-shaped bridge was estimated by eye. Tannenburg measured out five, ten and twenty inches from the approximate tangent positions on the keyboard for the notes $c^3$, $c^2$ and $c^1$ and made a mark on the soundboard. These marks were then joined together to form a curved line, which he then used to as a guide for determining the bridge shape.[42]

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41 Many of the surviving anonymous seventeenth- and early eighteenth-century clavichords have essentially straight bridges, such as the Anonymous clavichord No.21, Russell Collection, University of Edinburgh.

42 T. McGeary, "David Tannenberg and the clavichord in 18th-century America," *The Organ Yearbook*, XIII (1982), p.105.

## THE EARLY HAMBURG SCHOOL OF INSTRUMENT MAKING

There are no known surviving Hamburg-made clavichords which date from before the early 1720's. In order to find the origins of clavichord making in the city, therefore, it is necessary to investigate other musical instrument-making traditions in Hamburg, whose ancestry is more clearly defined. Since some organ builders are known to have made clavichords the tradition of organ manufacture in the city would seem to be a good starting point. Indeed, circumstantial evidence does in fact point to Hamburg organ builders making clavichords: the seventeenth-century clavichord builder Claus Dohausen of Brunswick, for example, studied instrument making with the Hamburg organ builder Gottfried Fritzsch.[43] The tradition of keyboard instrument making had certainly been laid in the mid-sixteenth century when Hamburg was the major North European centre of organ building. During the period from approximately 1540 to 1640 organ building in North-West Germany was dominated by three generations of the Scherer family of Hamburg, while the 150 organs either built or repaired by Arp Schnitger (1648-1719) of Hamburg over a fifty-year period (1666-1719) represent the peak of German organ building in the Baroque period.[44]

The very high standard of workmanship set by the luthier Joachim Tielke (1641-1719), resident in Hamburg from about 1667, must have also influenced later clavichord builders. Important for the later tradition of clavichord building in Hamburg is the fact that Tielke was the brother-in-law to Johann Fleischer I and was godfather to several of Fleischer's children. Tielke was a native of Königsberg rather than Hamburg and some writers have suggested that he learnt his skills in Brescia:

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43 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.35.

44 P. Williams, *The European Organ 1450-1850* (London: B.T. Batsford, 1966), pp.111-5.

Königsberg had close ties with Brescia during this time and the shape of the sound-holes of Tielke's viols are supposedly similar to those of Brescian instruments.[45] Tielke's work must have been held in high esteem throughout much of Europe, for both King Frederik IV of Denmark and the Elector Johann Wilhelm von der Pflaz are known to have commisioned instruments from him. In order to impress his many noble patrons, Tielke often took considerable trouble over the decoration of his instruments: as well as using ivory, tortoise-shell and mother-of-pearl as veneers, he also inlaid precious and semi-precious stones. The bass viol made in Hamburg in 1691 by Tielke and preserved at the Bayerisches Nationalmuseum in Munich (inventory number 39), together with the baryton he made in 1686, now at the Victoria and Albert Museum in London (inventory number 115-1865) are especially splendid examples of Tielke's work.

**The clavichords of Johann Fleischer II**

The earliest surviving clavichords from Hamburg are signed by Johann Fleischer II. Four Fleischer-signed clavichords are currently known to exist, all of which date from the 1720's. The author has examined three of these: two (the 1722 JF[46] and 1728 JF[47]) are relatively small, fretted instruments with the chromatic compass C-$c^3$; the third (the 1723 JF[48]) is an unfretted instrument with the compass FF-$d^3$. The other extant Fleischer clavichord is reported also to have a C to $c^3$ compass. The 1728 JF is bichord strung throughout, but both the 1722 JF and 1723 JF also have a set of octave strings in the bass. Since these instruments represent the state

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45 G. Hellwig, "Joachim Tielke," *The Galpin Society Journal*, XVII (1964), p.30.

46 This instrument is preserved at the Stiftelsen Musikkulturens Framjande, Stockholm, inv. no. KL46.

47 This instrument is preserved at Ringve Museum, Trondheim, inv. no. RMT 386.

48 This instruement is preserved at the Drottningholm Teatermuseum, Stockholm. There is no inventory number.

of clavichord building in Hamburg immediately prior to Hass, a detailed description of them is warranted.

The case sides, baseboard and lid of all three instruments examined are made from a red coniferous wood. Although the wood has not been microscopically examined, it is most likely to be Scots Pine (*Pinus sylvestris*). The case sides are about 13½mm thick and are dovetailed together to form a rectangular frame, which is strengthened with two transverse keywell braces tenoned into mortises in the spine. At the case front the upper section of both braces is dovetailed to the main frame and the lower section is tenoned into a mortise. This basic case structure is secured to the upper surface of the baseboard with glue and pine dowels. The baseboard itself consists of two edge-jointed planks of pine about 21mm thick.

My investigations have shown that the outside case measurements (without the baseboard mouldings) and the case height (excluding the thickness of the baseboard) of Fleischer clavichords can be expressed as near multiples of the Hamburg Zoll. Table 2.2 below gives these case dimensions in millimetres together with their nominal Hamburg equivalents:

**Table 2.2**
**The case dimensions of Fleischer clavichords**

| | Length | | | Width | | | Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) |
| C to $c^3$ model | | | | | | | | | |
| 1722 JF | 62 | 1480.2 | 1475½ | 18 | 429.7 | 430 | 5¼ | 125.3 | 123 |
| 1728 JF | 62 | 1480.2 | 1478 | 18 | 429.7 | 429 | 5¼ | 125.3 | 125 |
| FF to $d^3$ model | | | | | | | | | |
| 1723 JF | 69¾ | 1665.2 | 1665 | 20½ | 489.4 | 487 | 6 | 143.2 | 141 |

The bottom fifteen notes (C to d) of the two C to $c^3$ instruments are unfretted, the rest are fretted in pairs, except for the notes a, $d^1$, $a^1$ and $d^2$. The rack, which determines the key splaying and tangent spacing, is glued against the inside of the spine between the two keywell braces. A comparison of rubbings made of the rack slots of all three Fleischer instruments examined has revealed that the rack-slot spacing and therefore the splaying pattern of the keys between the notes C and $c^3$ is precisely the same for all three. This indicates that Fleischer used a rack stick to mark out the slot spacing, and may imply that Fleischer's usual model of clavichord was the four-octave fretted clavichord, and that the unfretted FF to $d^3$ instrument was a special order. To extend the compass by nine notes for the unfretted clavichord Fleischer simply added two additional slots at the treble end and seven at the bass end. A small black ink dot on the tail ends of the keylevers indicates that Fleischer transferred the rack-slot spacings to the keyplank (from which the keys were sawn) with a pen.

The entire width of the keys at the front of the naturals is close to 28½ Zolle (680.4, 684.7mm) for both C to $c^3$ instruments and near to 33½ Zolle (799.8, 797.4mm) for the FF to $d^3$ instrument. The average three-octave span or *stichmass* of the two fretted instruments is close to 20½ Zoll (nominally 489.4, actually 489mm) compared to an actual value of 492mm for the FF to $d^3$ instrument. The keylevers are made from lime (*Tilia vulgaris*) and rest on a balance rail of oak (*Quercus sp.*). Along the top of the balance rail, and in front of both the accidental and the natural rows of balance pins, are two balance cords about 1.5mm thick, which act as the fulcrum for the keys. The cords are glued to the balance rail at regular intervals, and attached to the ends of the rail with small wooden pegs.

The tops of the keylevers between the balance pin and the tangent are carved in two distinct patterns: the tops of the natural keylevers are chamfered to a central ridge, whereas those of the accidental keylevers are carved in a meander-like pattern. At either end of the main key carving, there is a pair of scallops. The natural plates of both the 1722 JF and the 1728 JF are made from ivory, whereas tortoise-shell is used as a covering for the natural keys of the 1723 JF. The sharp blocks of all instruments appear to be of ebonised lime: those of the two C to $c^3$ instruments are veneered in small diamond-shaped pieces of ivory and tortoise-shell arranged in a chevron pattern; and those of the 1723 JF are veneered in tortoise-shell, with an inlaid arabesque design in ivory.

Spruce (*Picea sp.*) is the most likely wood type for the soundboard, which is glued onto liners and the 8ft wrestplank in the right-hand portion of the clavichord. The bridges, made from European beech (*Fagus sylvatica*), are attached to the soundboard with glue and nailed from the underside. There are two soundbars of a coniferous wood glued to the underside of the soundboard of the 1722 JF and the 1723 JF: one, which acts as a cutoff bar, is positioned between the 4ft bridge and the case front; and the other, which acts as a 4ft hitchpin rail, is positioned between the two bridges. The 1728 JF, which is designed simply for pairs of 8ft strings, only has a cutoff bar which is positioned on the player's side of the 8ft bridge.

The mean $c^2$ length of the three Fleischer clavichords is 286.0mm, which is equivalent to 12 Hamburg Zolle (nominally 286.49mm). A stringed keyboard instrument with Pythagorean scalings and a $c^2$ length of about 285mm can usually be thought of as being designed for brass stringing throughout the entire compass, and for a pitch of about A415 Hz (see chapter 3, pp 60-77). Little can be said for certain about either the stringing material or the pitch of these instruments, however, because the string scalings (see table 2.3 on p.48) are not very Pythagorean. The equivalent $c^2$ length of both $c^1$ and $f^1$ of the 1728 JF, for instance, actually exceeds the real length of $c^2$, which may indicate that iron strings were used in this part of the compass in order to avoid string breakage. It is most likely, however, that all the notes of 8ft pitch were strung in brass. The irregular scalings of all three of these clavichords is clear evidence that Fleischer was not very concerned that the treble 8ft scalings should halve and double for every octave rise and fall in pitch. Indeed, since Fleischer used the same rack-slot spacing pattern for both fretted and unfretted instruments, it would be almost impossible for the scalings of both models to be Pythagorean.

**Table 2.3**
**String scalings of Fleischer clavichords**

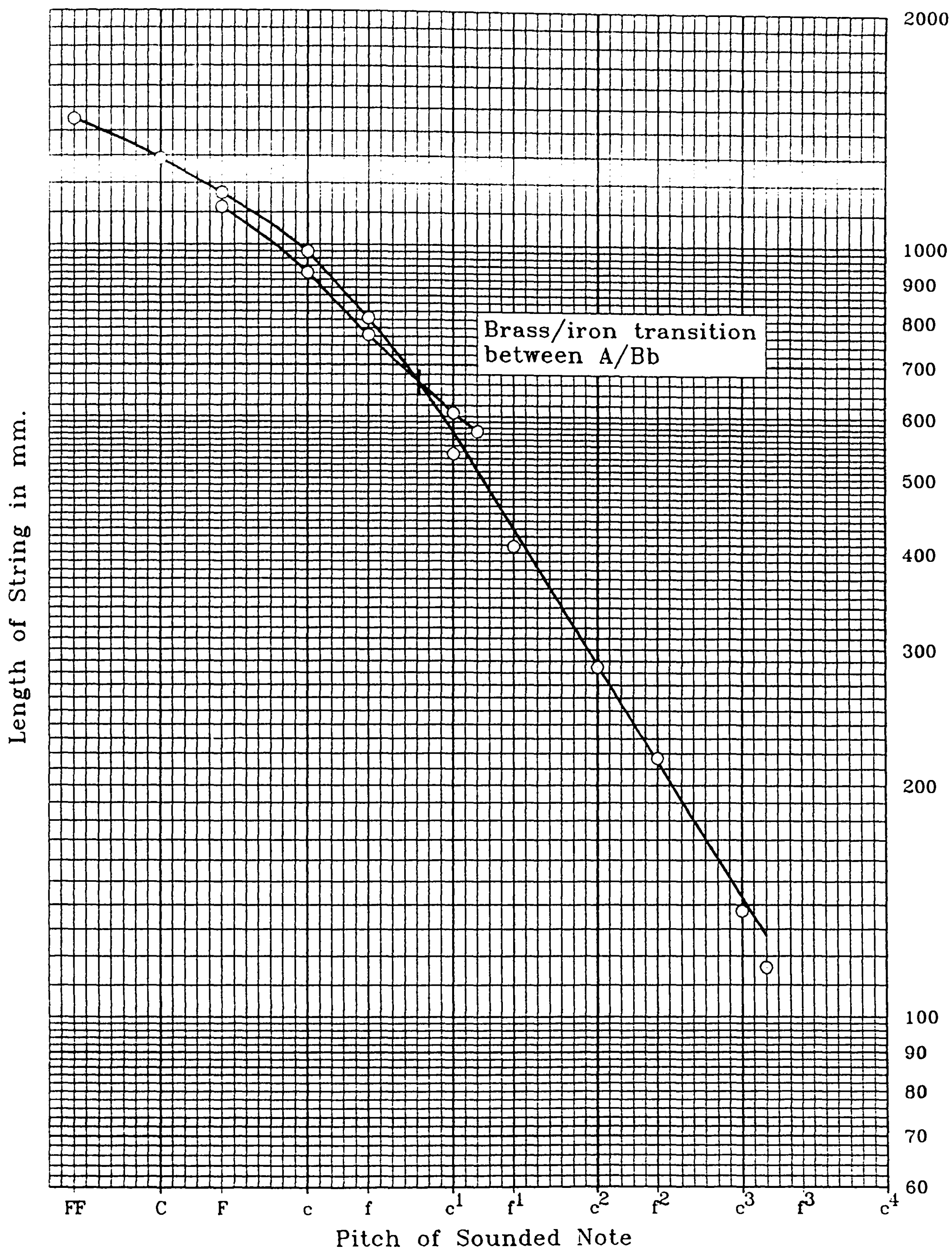
8ft Scalings

| | 1722 JF Length (mm) | 1722 JF $c^2$ equivalent | | 1723 JF Length (mm) | 1723 JF $c^2$ equivalent | | 1728 JF Length (mm) | 1728 JF $c^2$ equivalent |
|---|---|---|---|---|---|---|---|---|
| | | | $d^3$ | 116 | 260.4 | | | |
| $c^3$ | 130 | 260.0 | $c^3$ | 137½ | 275.0 | $c^3$ | 125 | 250.0 |
| $f^2$ | 213 | 284.3 | $f^2$ | 217 | 289.7 | $f^2$ | 210 | 280.3 |
| $c^2$ | 285 | 285.0 | $c^2$ | 285 | 285.0 | $c^2$ | 288 | 288.0 |
| $f^1$ | 430 | 287.0 | $f^1$ | 408 | 272.3 | $f^1$ | 457 | 305.0 |
| $c^1$ | 584½ | 292.3 | $c^1$ | 537 | 268.5 | $c^1$ | 608 | 304.0 |
| f | 819 | 273.3 | f | 804 | 268.3 | f | 828 | 276.3 |
| c | 971 | 242.8 | c | 980 | 245.0 | c | 971 | 242.8 |
| F | 1151 | 192.1 | F | 1165 | 194.4 | F | 1144 | 190.9 |
| C | 1266 | 158.3 | C | 1290 | 161.3 | C | 1255 | 156.9 |
| | | | FF | 1451 | 121.1 | | | |

4ft Scalings

| | 1722 JF Length (mm) | 1722 JF $c^2$ equivalent | | 1723 JF Length (mm) | 1723 JF $c^2$ equivalent |
|---|---|---|---|---|---|
| d | 544 | 305.3 | d | 574 | 322.1 |
| c | 584 | 292.0 | c | 606½ | 303.3 |
| F | 810 | 270.3 | F | 764 | 255.0 |
| C | 960 | 240.0 | C | 920 | 230.0 |
| | | | FF | 1117 | 186.4 |

**Graph 2.1**
**The string scalings of the 1723 JF**



It is difficult to interpret the 4ft string lengths of the 1722 JF and the 1723 JF, because the two sets of data are markedly different. It is likely, though, that the notes which do not exceed the nominal $c^2$ scaling of 12 Zolle (286.49mm) were intended to be strung, like the 8ft strings, in brass. However, the top few 4ft notes of both the 1722 JF and the 1723 JF have an equivalent $c^2$ length greater than 286.49mm and would probably break if strung in brass. Consequently, the top few notes of 4ft pitch were probably strung in iron, which has a greater tensile strength than brass. The brass/iron transition point can be determined by plotting both the 8ft and the 4ft string scalings on semi-logarithmic graph paper (see graph 2.1 on p.49). The point at which the short line joining the plotted 4ft lengths crosses that of the longer theoretical Pythagorean line (based on the nominal $c^2$ scaling of 286.49mm) is the brass/iron transition. Since the shape, size and positioning of the two 4ft bridges is different the transition from brass to iron occurs at different points: between the notes B and c on the 1722 JF and between A and $B^b$ on the 1723 JF.

**The origins of the bass 4ft strings**

The 1722 JF is the earliest example of a clavichord with a set of 4ft strings in the bass. The set of octave strings in the bass is such a standard feature of Hamburg clavichords that it is worthwhile considering its origins. The lute-making tradition in Hamburg under the leadership of Joachim Tielke, uncle to Johann Fleischer II, may be a precedent for the bass 4ft strings since it is also standard for lutes to have octave stringing in the bass.[49] Another possible precedent for the 4ft strings is the Hamburg organ-building tradition, which dates back to the time of the celebrated Scherer family in the middle of the sixteenth century: according to Peter

[49] On a German lute of this period all courses have just two strings. The treble courses are in unison, the bass courses in octaves. (Personal communication from Darryl Martin).

Williams the *bifara* stop is produced from two ranks of pipes, 8ft stopped and 4ft open.[50]

The reason for the top 4ft note usually being d is that this note is usually the highest note of fretted clavichords to have its own pair of strings. It would be impossible to design a fretting system which enabled adjacent notes of 8ft and 4ft pitch to be produced from the same course of strings, since the tangents would need to be further apart on the pair of 8ft strings than that required for the single shorter 4ft string. It is also interesting, although probably only coincidental, that the compass of the pedals on organs of the period, including that built by Arp Schnitger for the Nicolaikirche in Hamburg between 1682 and 1687[51] extended to $d^1$, the sounding pitch of the top 4ft note of most Hamburg-made clavichords.

**CONCLUSION**

Many features of the clavichords built by Johann Fleischer II look forward to the building practices of both Hieronymus and Johann Hass: the wood types, basic case structure and framing, soundboard layout and some design elements are common to both families of makers. Such similarities are often the result of an apprenticeship and/or families intermarrying, but in this case there is no evidence for any such formal contract having taken place between the two families. Hamburg instrument makers did, however, tend to live in close proximity to each other, and since signed and dated instruments by Hieronymus Hass and Johann Fleischer II overlap by eight years, Hass must have known the work of Fleischer and perhaps even his working methods as well.

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50 P. Williams, *The European Organ 1450-1850* (London: B.T. Batsford, 1966), pp.270-1.

51 P. Williams, *The European Organ 1450-1850* (London: B. T. Batsford, 1966), p.113.

# Chapter 3

## ELEMENTS IN THE DESIGN OF HASS CLAVICHORDS

### INTRODUCTION

Prior to the actual construction of a clavichord, Hieronymus and Johann Hass had to decide its compass, case dimensions, stringing, pitch and fretting pattern. My research has shown that while both members of the Hass family treated some of these elements as standard, others were almost continually being altered. Both makers always conformed to the contemporary instrumental pitch standard in Hamburg, for example, but do not appear to have viewed the overall case dimensions as anything other than transitory.

Although there are no surviving clavichords signed by both Hieronymus and Johann Hass, the instruments of father and son are so similar as not to warrant separate treatment. For instance, both makers used the same wood types, the same basic case structure, soundboard layout and stringing. Distinguishing features between the instruments of father and son include the length and width of the case, the rack-slot spacing pattern, the fretting pattern and the spacing of the bridge pins, hitchpins and tuning pins. It is important, however, to stress that these differences came about through an evolutionary development of a clavichord design carried on progressively by both father and son, and during the making of a large number of instruments. The name Hass will, unless specified, consequently refer to both makers.

## THE COMPASS OF HASS CLAVICHORDS

Hass made two standard models of clavichord: unfretted, FF to $f^3$ instruments, and smaller, fretted C to $d^3$ instruments.[1] These two models were built concurrently, at least during the period from about 1740 to 1760, since surviving C to $d^3$ instruments cover a thirty-three year period from 1728 to 1761, and the FF to $f^3$ instruments span a twenty-five year period from 1742 to 1767. Although it is not possible to be certain of the year in which Hieronymus Hass started making five-octave FF to $f^3$ clavichords, the two instruments dated 1742 are the earliest examples with this compass by any maker.[2]

Only seven C to $d^3$ Hass clavichords survive compared to sixteen FF to $f^3$ instruments, but this may not truly represent the relative numbers of each model actually made by Hass. The apparent dominance of the five-octave clavichord within the family's output may in fact be due to the preference of late eighteenth- and early nineteenth-century musicians and collectors. Due to their relatively narrow compass, the C to $d^3$ instruments may have been discarded earlier than the five-octave instruments and consequently it is possible that more have been lost. Indeed, the range of two narrow-compass Hass clavichords, the 1728 HH and the 1732b HH, has been extended from $d^3$ to $f^3$ by re-positioning the treble keywell brace to allow for three extra keys, adding three additional slots to the treble end of the rack, and by extending the treble end of the balance rail. This *petit ravalement*, or extension of the keyboard without widening the case, was presumably undertaken towards the end of the eighteenth century to enable both instruments to fulfil the later eighteenth-century musical requirements.

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[1] Throughout the text these two models will be discussed side-by-side.

[2] I am grateful to Dr Charles Mould for verifying this information for me.

In addition to building C to $d^3$ and FF to $f^3$ clavichords Hass may have occasionally made instruments to order. Both the 1732b HH with the compass FF to $d^3$ and the 1748 JH with the compass GG to $d^3$ may have been made as a special request, because they are the only surviving Hass clavichords with these particular compasses. Neither instrument is, however, unique within the overall output of Hass keyboard instruments, as two surviving Hass harpsichords, the 1721 HH and 17(2)6 HH both originally had the fifty-eight note compass FF to $d^3$, and the 1734 HH has the fifty-six note compass GG to $d^3$.

**CASE DIMENSIONS**

Since the compass of an instrument is an important factor in its overall size, Hass C to $d^3$ clavichords are smaller than those with the five-octave range of FF to $f^3$, and the two instruments with unique compasses, the 1732b JH and the 1748 JH have intermediate dimensions.

My investigations have shown that the case dimensions of Hass instruments can only be expressed as near multiples of the Hamburg Zoll. Table 3.1 gives the outside case dimensions in millimetres, excluding the thickness of the baseboard moulding, of seven clavichords - the earliest and latest extant signed C-$d^3$ and FF-$f^3$ instruments plus the three unique instruments - together with their nominal Hamburg equivalents. The same seven clavichords will be used throughout this chapter for comparative purposes.

**Table 3.1**
**Outside case dimensions**

**Standard models**

| | Length | | | Width | | | Average Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) |
| **C-d$^3$** | | | | | | | | | |
| 1728 HH | 63½ | 1516.0 | 1514 | 18 | 429.7 | 432 | 5 | 119.4 | 120 |
| 1761b JH | 65$^2/_3$ | 1567.7 | 1567 | 18$^3/_4$ | 447.6 | 448 | 5 | 119.4 | 116 |
| **FF-f$^3$** | | | | | | | | | |
| 1742a HH | 71 | 1695.1 | 1698 | 22 | 525.2 | 524 | 5$^3/_4$ | 137.3 | 138 |
| 1767 JH | 72$^3/_4$ | 1736.8 | 1738 | 22½ | 537.2 | 537 | 6¼ | 149.2 | 151 |

**Unique models**

| | Length | | | Width | | | Average Height | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) |
| **FF-d$^3$** | | | | | | | | | |
| 1732b HH | 71½ | 1707.0 | 1709 | 21 | 501.4 | 496 | 5$^3/_4$ | 137.3 | 139 |
| **GG-d$^3$** | | | | | | | | | |
| 1748 JH | 70 | 1671.2 | 1672 | 21½ | 513.3 | 512 | 5$^3/_4$ | 137.3 | 134 |
| **FF-f$^3$ (3x8ft)** | | | | | | | | | |
| 1761a JH | 72½ | 1730.9 | 1729½ | 22 | 525.2 | 523 | 5$^3/_4$ | 137.3 | 137½ |

The fact that the outside dimensions of standard Hass models cannot generally be quantified in whole units of Hamburg measure is, however, not particularly surprising since the outside case measurements are determined by the case thickness. It is the inside edges that must have been scribed during the construction of the corner dovetail joints, and it would, therefore, seem more likely that the inside case scantlings (given in table 3.2) should be more easily expressed in terms of Hamburg's local unit of measure.

**Table 3.2**
**Inside case dimensions**

**Standard models**

| | Length | | | Width | | |
|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) |
| **C to $d^3$** | | | | | | |
| 1728 HH | 62¼ | 1486.2 | 1484 | $16^3/_4$ | 399.9 | 402 |
| 1761b JH | 64½ | 1539.9 | 1538 | $17^2/_3$ | 421.8 | 422 |
| **FF to $f^3$** | | | | | | |
| 1742a HH | $69^3/_4$ | 1665.2 | 1665 | 20½ | 489.4 | 490 |
| 1767 JH | $71^1/_3$ | 1703.0 | 1703 | 21 | 501.4 | 504 |

**Unique models**

| | Length | | | Width | | |
|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Zolle) | (mm) | (mm) |
| **FF to $d^3$** | | | | | | |
| 1732b HH | $70^1/_3$ | 1679.1 | 1679 | $19^2/_3$ | 469.5 | 468 |
| **GG to $d^3$** | | | | | | |
| 1748 JH | $68^3/_4$ | 1641.3 | 1642 | $20^1/_3$ | 485.4 | 486 |
| **FF to $f^3$ (3x8ft)** | | | | | | |
| 1761a JH | 71 | 1695.1 | 1694 | 20½ | 489.4 | 489 |

The inside measurements too are poorly expressed in terms of the Hamburg Zoll, and this may indicate that the Hass family placed little importance on the overall dimensions of their clavichords. The length, for example, may have been determined simply by adding together the dimensions of three smaller spans: a non-critical and variable span in front of the toolbox; a regularized keywell length; and the case in front of the soundboard whose length was periodically extended.

Variations in the case dimensions occur between instruments of different compasses, between those instruments built by Hieronymus and those by Johann Hass, and between those instruments built at the beginning and at the end of each of their working careers. The C to $d^3$ models of Johann Hass are, for example, slightly larger than those of his father: all four signed Hieronymus Hass examples measure $63\frac{1}{2}$ Zolle (nominally 1516.0mm, case average 1515.0mm) long by 18 Zolle (429.7mm, 430.8mm) wide; while the 1746 JH measures 66 Zolle (1575.7mm, 1574mm) long by $18\frac{1}{2}$ Zolle (441.7mm, 445mm) wide. Since both members of the Hass family use the same keywell length the extra case length of Johann Hass instruments is purely the result of a longer right-hand case front. Similarly, the case dimensions of the standard five-octave clavichords increase in size chronologically: the four clavichords dating from 1742 and 1743 are all 71 Zolle (1695.1mm, 1700.8mm) long by 22 Zolle (525.2mm, 520.8mm) wide; while both the 1761c JH and 1763a JH are $72\frac{1}{2}$ Zolle (1730.9mm, 1729.5mm) long by $22^1/_3$ Zolle (533.2mm, 534.5mm) wide. As with the C to $d^3$ instruments, the increase in overall case length of the FF to $f^3$ instruments is due to the case in front of the soundboard being longer: the right-hand case front of the 1742a HH, for example, measures $30\frac{1}{2}$ Zolle (728.2mm, 728mm) compared to a length of $32\frac{1}{4}$ Zolle (769.9mm, 770mm) for the 1767 JH.

The amount by which the case dimensions were increased was not determined haphazardly, however, since the instruments with longer case sides are proportionally wider front to back. In fact the length-to-width ratio of all signed C to $d^3$ Hass clavichords by both father and son is very close to 7:2, and the length-to-width ratio of all standard FF to $f^3$ models is near to 13:4. Table 3.3 shows that the measured case widths of standard instruments are in close agreement with the theoretical widths determined from the case length. The small percentage error is, in fact, well within the error of measurment. If the case dimensions were determined by proportion this does, of course, explain why the length and width of Hass clavichords can only rarely be expressed as exact multiples of the Hamburg Zoll. Compared to standard clavichords, the length-to-width ratios of the three unique instruments are less accurately expressed as a proportion. The length-to-width ratio of the 1732b HH, for instance, may be 24:7, but it is also close to both 17:5 and 7:2. The difficulties in expressing the case dimensions of the three special clavichords as a proportion does, however, confirm the liklihood that these instruments were built to order, using only some standard lengths. The unusual length-to-width ratio of the trichord-strung 1761a JH is, for instance, a consequence of the instrument having a case length typical of normal Johann Hass FF to $f^3$ clavichords, but having a case width which is about $^1/_3$ Zolle narrower.

**Table 3.3**
**Case proportions**

**Standard models**

| Instruments | Compass | Case Proportion | Actual Length | Calculated Width | Actual Width | % Error |
|---|---|---|---|---|---|---|
| 1728 HH | C to $d^3$ | 7:2 | 1514 | 432.6 | 432 | 0.1 |
| 1761b JH | C to $d^3$ | 7:2 | 1567 | 447.7 | 448 | 0.1 |
| 1742a HH | FF to $f^3$ | 13:4 | 1698 | 522.5 | 524 | 0.3 |
| 1761c JH | FF to $f^3$ | 13:4 | 1729 | 532.0 | 534 | 0.4 |
| 1767 JH | FF to $f^3$ | 13:4 | 1738 | 534.8 | 537 | 0.4 |

**Unique models**

| Instrument | Compass | Case Proportion | Actual Length | Calculated Width | Actual Width | % Error |
|---|---|---|---|---|---|---|
| 1732b HH | FF to $d^3$ | 24:7? | 1709 | 498.5 | 496 | 0.5 |
| 1748 JH | GG to $d^3$ | 13:4 | 1672 | 514.5 | 512 | 0.5 |
| 1761a JH | FF to $f^3$ | 10:3? | 1729½ | 518.9 | 523 | 0.8 |

## FRETTING

All C to $d^3$ models are fretted, and all standard five-octave FF to $f^3$ models are unfretted.[3] Of the special models the FF to $f^3$ trichord-strung 1761a is fretted, and both the 1732b HH and the 1748 JH (with a compass of FF to $d^3$ and GG to $d^3$ respectively) are unfretted. All but one of the five extant Hieronymus Hass C to $d^3$ fretted clavichords have thirty-six pairs of 8ft strings, a separate course for each of the bottom fifteen notes C to d, and then pairwise fretting from $e^b$-e upwards except for the notes a, $d^1$, $a^1$, $d^2$, $a^2$ and $d^3$ which are free:

$e^b$-e, f-f#, g-g#, a, $b^b$-b, $c^1$-$c^{\#1}$, $d^1$, $e^{b1}$-$e^1$, $f^1$-$f^{\#1}$, $g^1$-$g^{\#1}$, $a^1$, $b^{b1}$-$b^1$, $c^2$-$c^{\#2}$, $d^2$, $e^{b2}$-$e^2$, $f^2$-$f^{\#2}$, $g^2$-$g^{\#2}$, $a^2$, $b^{b2}$-$b^2$, $c^3$-$c^{\#3}$, $d^3$

The one exception to this pattern is the (1725) HH. One of the reasons for assigning the instrument this date is that it has one fewer pairs of 8ft strings than the other Hieronymus Hass clavichords. The pairwise fretting starts at $e^b$-e, except for the notes a, $d^1$, $a^1$ and $d^2$ which are free, and the top six notes are fretted as: $a^2$-$b^{b2}$, $b^2$-$c^3$, and $c^{\#3}$-$d^3$. In contrast to the normal design of his father with thirty-six pairs of 8ft strings, Johann Hass C to $d^3$ clavichords have thirty-seven pairs of 8ft strings, with a separate course for the bottom sixteen notes C to e, and pairwise fretting from f-f# upwards except for the notes a, $d^1$, $a^1$, $d^2$, $a^2$ and $d^3$ which are free.[4]

The stringing of the 1761a JH deserves special mention not only because it is triple-strung throughout the entire five-octave compass, but also because it is fretted.[5] There is the usual stringing in the bass from FF to B, consisting of one 4ft and two 8ft strings per course, and then three sets of 8ft strings from c to $f^3$. If this clavichord had been designed to be unfretted one hundred and sixty-four 8ft

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3 The five-octave 1743a HH is not fretted in the conventional sense, since only the tangents for the two notes $e^{b3}$ and $e^3$ use the same course. I believe that this may have been the remedy of a marking-out mistake, since if the bridge pin holes were drilled incorrectly with one fewer pair than required, a simple remedy - rather than plugging the holes and starting again - is to fret two notes together.

4 For a discussion on the effect this has on the bridge shape and length of the soundboard front and right-hand case front, see chapter 4.

5 The only other clavichord known to have three sets of 8ft strings is the clavichord made in Schweinfurth in 1751 by F. Kiedolps. This instrument, which has the compass C,D to $e^3$, is preserved at the Smithsonian Institution, Washington D.C., inv. no.303.540.

strings would have been required. This would have meant that the string band was excessively wide and the treble keylevers too long to be playable. By designing the instrument for pairwise fretting from f-f# upwards, except for the a's and d's which are free, Johann Hass needed only one hundred and nineteen 8ft strings (compared to standard unfretted FF to $f^3$ clavichords which have one hundred and twenty-two 8ft strings) and was able to use keylevers of standard length and mechanical advantage.

This instrument is an example of the Hass family's attitude towards clavichord manufacture. Rather than being content to make clavichords of the same form year after year, both father and son were constantly re-thinking and developing their designs. This instrument, for instance, may have been built as part of an experiment to increase the potential loudness of the clavichord, since as well as designing the clavichord to be trichord-strung throughout the entire compass the designated string gauges are somewhat heavier than normal. Not only do three strings sound 1.76 decibels louder than two strings, but three strings of thicker wire also radiate more sound, and offer more resistance to the player's fingers, which enables them to be struck more forcefully than two strings of lighter gauge.

## THE STRINGING OF HASS CLAVICHORDS

### Introduction

Standard Hass clavichords are designed for trichord-stringing in the bass and bichord-stringing in the tenor, alto and treble. Throughout the compass the unison 8ft strings are arranged in pairs, and centrally positioned between each pair in the bass is a string of 4ft pitch. The bass 4ft strings have their own separate bridge, which in most cases is straight. The two earliest surviving Hieronymus Hass clavichords, however, the (1725) HH and the 1728 HH, have slightly curved 4ft bridges matching the shape of the 8ft bridge. A curved 4ft bridge has, however, only minimal beneficial effect on the string scalings or soundboard layout and, in any case, a straight bridge is much easier to make.

Rather than using overspun strings in the bass to improve the clarity of the bass tone both father and son used 4ft strings, usually up to d, to enrich the harmonic structure. As the bass 8ft strings are foreshortened in order to keep the case length of the clavichord within practical limits, they are not long enough to have their full harmonic structure. The 4ft strings compensate for this by providing some of the upper partials which would otherwise be missing.[6]

**Eighteenth-century instrumental pitch in Hamburg**

It is clear from the research undertaken by Grant O'Brien that historical keyboard instrument makers designed their instruments so that the strings were near to breaking point.[7] Consequently, the design pitch of Hass clavichords is fundamental to our understanding of their stringing. At the time of the Hass family there were two basic pitches in use in Hamburg, a high church pitch and a lower chamber (instrumental) pitch. Although some builders, notably Ruckers, are known to have built keyboard instruments at a variety of pitches, there is no indication that the Hass family intended their clavichords to be tuned to anything other than a single pitch. But what would that pitch have been?

In a paper originally presented in 1880[8] Arthur Ellis recorded the pitch of three different Hamburg organs: the pitch of the organ in the Catharinenkirche was at high Church Pitch A480.8 Hz; the organ in the Michaeliskirche, built by Hildebrandt

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[6] For a scientific analysis of the effect of the 4ft strings on the timbre of the bass notes see chapter 5, pp.165-9.

[7] G. O'Brien, "The Stringing and pitches of Ruckers instruments," *Colloquium: Ruckers Klavecimbels en Copieën* (Antwerp, 1977), pp.48-71.

in 1762, was at chamber pitch A407.9 Hz; and the Schnitger organ at the Jacobikirche, formerly at A489.2 Hz, but now tuned to A495 Hz, originally possessed an 8ft gedact which was about a minor third lower than the rest of the organ, at chamber pitch A411.4 Hz. The supposed existence of the *Cammerton* stop on the Jacobikirche is very interesting and probably implies that there was a tradition of instrumental performance in this church as there was in the Catharinenkirche.[9] The existence of two pitch standards in Hamburg at this time is confirmed by the musician and critic Johann Mattheson,[10] who wrote in 1713 that:

> Ob nun / oder warum dieser oder jener Thon / a, oder b Cammer- Chor- oder Opern-Thon heist / daran liegt im Grunde nichts. Der Chor-Thon ist 9 bis 14 Commata höher als der Opern- und Cammer-Thon.

> Now, whether and why this or that tone is called a or b, Chamber, Choir or Opera Pitch - this is basically of no consequence. Choir Pitch is 9 to 14 commas higher than opera or chamber pitch.

The survival of two sets of manuscript parts of Bach's Cantata No.21, *Ich hatte viel Bekümmernis*, one of which is thought to have been prepared for use in Hamburg, also sheds some light on the pitch standard in Hamburg at the time of the Hass family. Both the oboe and bassoon parts for the original performance in Weimar of the cantata, on the Third Sunday after Trinity, the 17th June, 1714, are written a tone higher (in d minor) than the strings, voices and continuo (in c minor). Both Mendel and Brainard have concluded that the strings and singers took their pitch from the organ at *Chorton*, while the oboe and bassoon were at *Cammerton*; the woodwind parts were notated a tone higher than the rest of the parts in order to

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8 A. Ellis, "On the History of Musical Pitch," *Journal of the Society of Arts* (March, 1880), pp.293-404; republished in *Studies in the History of Musical Pitch* (Amsterdam: Knuf, 1968), pp.11-62.

9 See chapter 1, p.17.

10 J. Mattheson, *Das neu-eröffnete Orchestre* (Hamburg, 1713); trans. A. Mendel & E. Ellis, *Studies in the History of Musical Pitch* (Amsterdam: Knuf, 1968), p.192.

compensate for their actual pitch a tone lower.[11] Schulze has shown, through the use of watermarks and scribal evidence, that a second set of string parts, in d minor, were written during the winter of 1720, probably in preparation for Bach's audition for the post of organist at the Jacobikirche in Hamburg in November 1720.[12] Since the organ at the Jacobikirche possessed a single stop at *Cammerton* pitch, however, there was no need to copy out any transposing parts. Consequently, Bach either didn't know about the *Cammerton* stop, or he wanted to make use of the full organ at *Chorton*.

A simple comparison of Johann Hass harpsichord scalings with those of Pascal Taskin (1723-93), court instrument maker to Louis XV of France, suggest that there existed a similar pitch standard in Hamburg and Paris. Table 3.4 shows that the treble scalings of the double-manual harpsichord made in Paris in 1769 by Pascal Taskin[13] are very similar to those of the single-manual harpsichord made in Hamburg in 1764 by Johann Hass.[14] Since Pascal Taskin's tuning fork is reported to have been at A409 Hz,[15] there is a strong case, assuming that both makers were using Nuremburg wire with the same mechanical properties, for tuning Hass instruments to a similar pitch standard. It is consequently appropriate to tune the keyboard instruments of Hieronymus and Johann Hass to a pitch somewhere between

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[11] A. Mendel, "On the pitches in use in Bach's Time - I," *The Musical Quarterly*, XLI (1955), p.342; P. Brainard, "Cantata 21 Revisited," *Studies in Renaissance and Baroque Music in Honour of Arthur Mendel*, ed. R. Marshall (Basel: Bärenreiter Kassel, 1974), pp.231-42.

[12] G. Stauffer, "Johann Mattheson and J.S. Bach," *New Mattheson Studies*, ed. G. Buelow & H.J. Marx (Cambridge: Cambridge University Press, 1983), p.358.

[13] The harpsichord is at the Russell Collection, University of Edinburgh, Edinburgh, Collection No.15.

[14] Russell Collection No.14.

[15] A. Ellis & A. Mendel, "On the History of Musical Pitch," *Studies in the History of Musical Pitch* (Amsterdam: Knuf, 1968), p.36.

A407.9 Hz (of the Michaeliskirche organ) and A411.4 Hz (of the 8ft gedact on the Jacobikirche organ), that is at A409 Hz.

**Table 3.4**
**Harpsichord scalings of the 1764 Hass and the 1769 Taskin**

| | | 1764 JH | | | 1769 PT | | |
|---|---|---|---|---|---|---|---|
| Note | Long 8ft | Short 8ft | 4ft | Long 8ft | Short 8ft | 4ft | Note |
| $f^3$ | 141 | 135½ | 66½ | 149 | 144 | 71 | $f^3$ |
| $c^3$ | 183½ | 175½ | 89 | 188 | 181 | 86 | $c^3$ |
| $f^2$ | 272 | 259 | 129 | 269 | 256½ | 122 | $f^2$ |
| $c^2$ | 362½ | 346½ | 172½ | 357½ | 339 | 162½ | $c^2$ |
| $f^1$ | 532½ | 511 | 258 | 539 | 514 | 250½ | $f^1$ |
| $c^1$ | 694½ | 667 | 350½ | 711 | 678 | 338 | $c^1$ |
| f | 975 | 944 | 522 | 983 | 950 | 488 | f |
| c | 1184 | 1153 | 650 | 1179 | 1145 | 606 | c |
| F | 1483 | 1450 | 859 | 1444 | 1414 | 775 | F |
| C | 1675 | 1656 | 1003 | 1618 | 1591 | 899½ | C |
| FF | 1819 | 1808 | 1212 | 1766 | 1757 | 1074 | FF |

**String scalings**

Hass took considerable care over the marking out of the bridges and the splaying pattern of the keys in order to obtain very accurate string scalings. Both the 8ft and the 4ft string scalings of the earliest and latest signed C to $d^3$ and FF to $f^3$ clavichords, plus the three special models are listed in table 3.5, and plotted as Graphs 3.1 to 3.7. The bass limits of Pythagorean scalings are shown in table 3.5 by underlining. The range, mean, and the rms deviation (calculated as the square root of the mean of the squares of the deviation from the mean), together with the $c^2$ equivalent for the mean values, and the nominal equivalent in Hamburg Zolle are given for all the signed C to $d^3$ in table 3.6 and for all standard FF to $f^3$ clavichords in table 3.7.

## Table 3.5
## Hass 8ft and 4ft scalings

| | C to $d^3$ models | | FF to $f^3$ models | | unique models | | |
|---|---|---|---|---|---|---|---|
| | 1728 HH | 1761b JH | 1742a HH | 1767 JH | 1732 HH FF-$d^3$ | 1761a JH FF-$f^3$ | 1748 JH GG-$d^3$ |
| $f^3$ | --- | --- | 105 | 103 | --- | 105 | --- |
| $d^3$ | 122 | 122 | --- | --- | 126½ | --- | 124 |
| $c^3$ | 142 | 143½ | 141 | 140 | 141 | 141 | 143 |
| $f^2$ | 222 | 218 | 213 | 215 | 212 | 216 | 215½ |
| $c^2$ | 291 | 285 | 284 | 287 | 285 | 284 | 286½ |
| $f^1$ | 432 | 437½ | 426 | 423 | 422½ | 425 | 431 |
| $c^1$ | 579 | 567 | 570 | 567 | 574 | 564 | 561 |
| f | 836 | 829 | 813 | 850 | 832 | 807 | 808 |
| c | 1015 | 1017 | 986 | 1043 | 999 | 1001 | 991 |
| F | 1190 | 1221 | 1189 | 1238 | 1206 | 1210 | 1195 |
| C | 1292 | 1328 | 1304 | 1347 | 1324 | 1328 | 1315 |
| FF | --- | --- | 1445 | 1489 | 1465 | 1471½ | (GG) 1420 |

### Hass 4ft Scalings

| | 1728 HH | 1761b JH | 1742a HH | 1767 JH | 1732 HH | 1761a JH | 1748 JH |
|---|---|---|---|---|---|---|---|
| d | 576 | 582 | 572 | --- | 568 | --- | 575 |
| c | 607 | 631½ | 616½ | 597 | 618 | (B) 664 | 623 |
| F | 794½ | 820 | 777 | 778 | 786 | 813 | 796 |
| C | 926 | 957 | 900 | 915 | 916 | 944 | 927 |
| FF | --- | --- | 1080 | 1128 | 1103 | 1138 | (GG) 1060 |

## Table 3.6
## Average 8ft scalings
## of all signed C to $d^3$ clavichords

| | Range (mm) | Mean (mm) | $c^2$ equivalent | rms deviation | Nominal (Zolle) | Nominal (mm) |
|---|---|---|---|---|---|---|
| $d^3$ | 121-126 | **122.9** | 275.9 | 1.59 | 5¼ | **125.3** |
| $c^3$ | 140-143½ | **141.9** | 283.8 | 1.17 | 6 | **143.2** |
| $f^2$ | 215-222 | **218.6** | 291.8 | 2.17 | 9 | **214.9** |
| $c^2$ | 285-291 | **287.8** | 287.8 | 2.10 | 12 | **286.5** |
| $f^1$ | 427-437½ | **432.6** | 288.7 | 3.42 | 18 | **429.7** |
| $c^1$ | 563-579 | **569.4** | 284.7 | 5.70 | 24 | **573.0** |
| f | 815-836 | **824.7** | 275.2 | 7.23 | 34½ | **823.7** |
| c | 1003-1020 | **1012.1** | 253.0 | 6.17 | $42^1/_3$ | **1010.7** |
| F | 1190-1221 | **1206.0** | 201.2 | 12.36 | 50½ | **1205.6** |
| C | 1292-1336 | **1315.0** | 164.4 | 17.13 | 55 | **1313.1** |

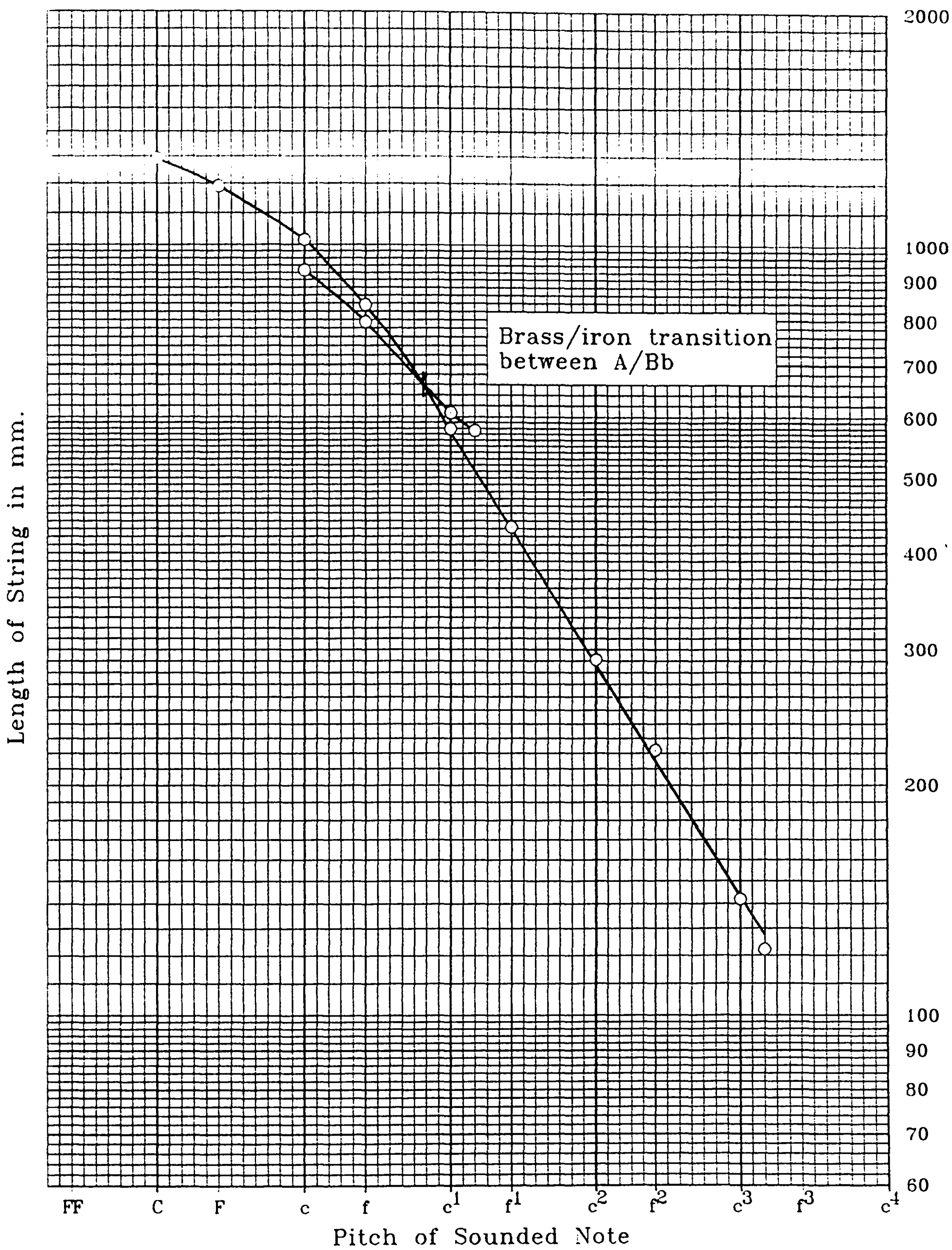
**Table 3.7**
**Average 8ft scalings**
**of all standard FF to $f^3$ clavichords**

| | Range (mm) | Mean (mm) | $c^2$ equivalent | rms deviation | Nominal (Zolle) | Nominal (mm) |
|---|---|---|---|---|---|---|
| $f^3$ | 102-107 | **104.3** | 278.4 | 1.28 | $4\frac{1}{2}$ | **107.4** |
| $c^3$ | 139-144 | **141.1** | 282.2 | **1.47** | 6 | **143.2** |
| $f^2$ | 210-216 | **213.4** | 284.9 | 1.98 | 9 | **214.9** |
| $c^2$ | 282-288 | **285.8** | 285.8 | **1.77** | 12 | **286.5** |
| $f^1$ | 420-438 | **426.6** | 284.7 | 5.16 | 18 | **429.7** |
| $c^1$ | 562-577 | **568.5** | 284.3 | **3.75** | 24 | **573.0** |
| f | 807-850 | **824.7** | 278.0 | 11.47 | $34\frac{1}{2}$ | **823.7** |
| c | 986-1043 | **1008.4** | 252.1 | 16.07 | $42\frac{1}{4}$ | **1008.7** |
| F | 1189-1238 | **1208.7** | 201.7 | 12.06 | $50^2/_3$ | **1209.6** |
| C | 1304-1347 | **1322.4** | 165.3 | 10.15 | $55\frac{1}{2}$ | **1325.0** |
| FF | 1445-1489 | **1465.2** | 122.2 | 11.62 | $61^1/_3$ | **1464.3** |

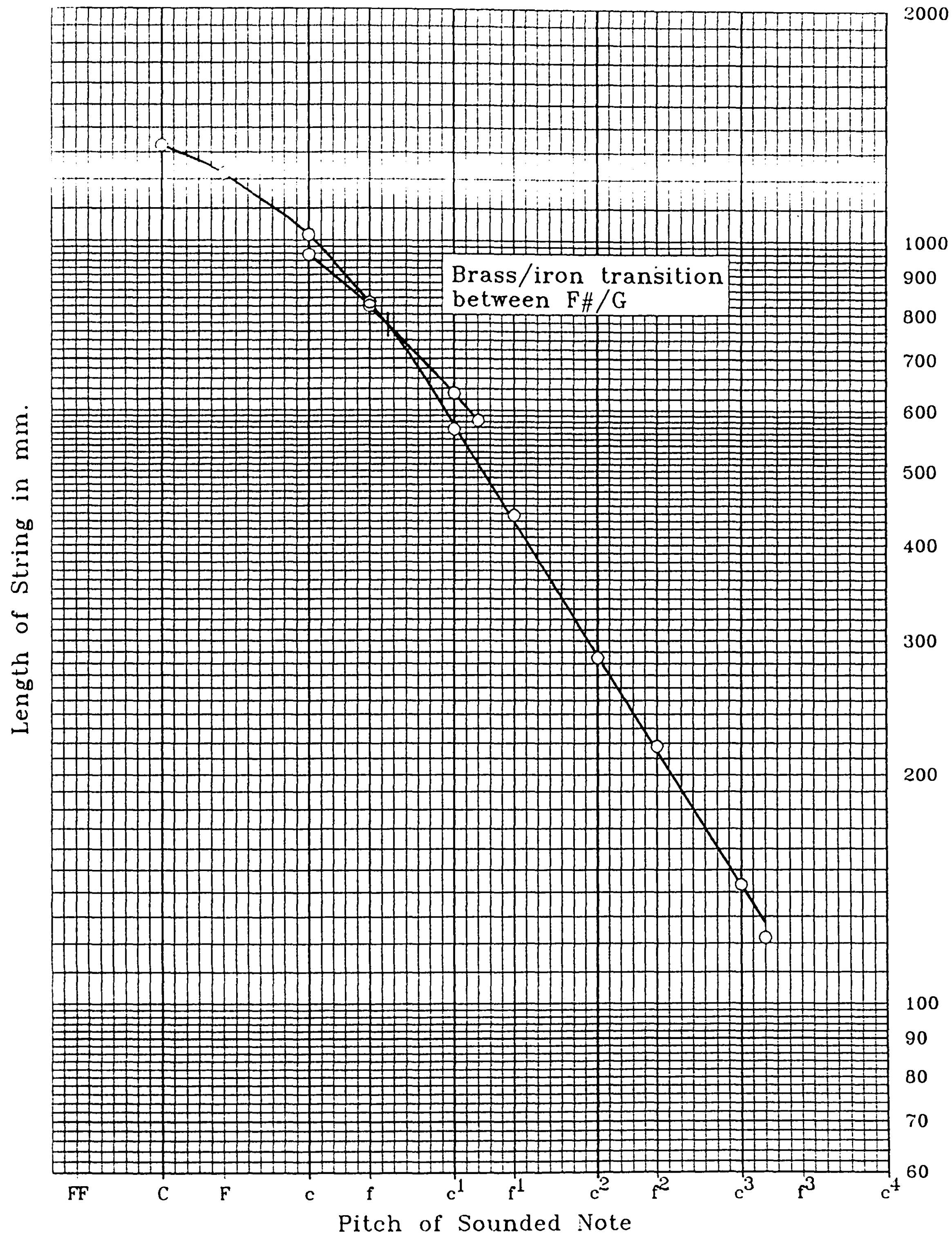
Using the root mean square of all Hass clavichord 8ft scalings of both the C to $d^3$ and FF to $f^3$ models, it was found that the notes $c^1$, $c^2$ and $c^3$ have the smallest rms deviations. This is of great importance since it may indicate that Hass marked the 8ft bridge out based on these three c's. The value for $c^2$ is especially accurate since at this note an imaginary line joining the tangent to the bridge pin (and corresponding to the strings) is nearest to being perpendicular to the strings.

The 8ft strings of Hass clavichords usually halve and double in length with every octave rise and fall in pitch from about $c^1$ upwards, and below this the scalings foreshorten in the usual way. The 8ft string scalings of two Johann Hass C to $d^3$ clavichords, the 1746 JH and the 1761b JH, are Pythagorean only from $f^1$ upwards, however, while the scalings of the FF to $f^3$ 1767 JH are exceptional in that they are Pythagorean from f upwards. The Pythagorean nature of the treble 8ft string lengths (shown by a straight line on the scaling graphs) enables them to be represented by the mean $c^2$ scaling of 286.2mm, a value equivalent to twelve Hamburg Zolle (nominally 286.49mm).

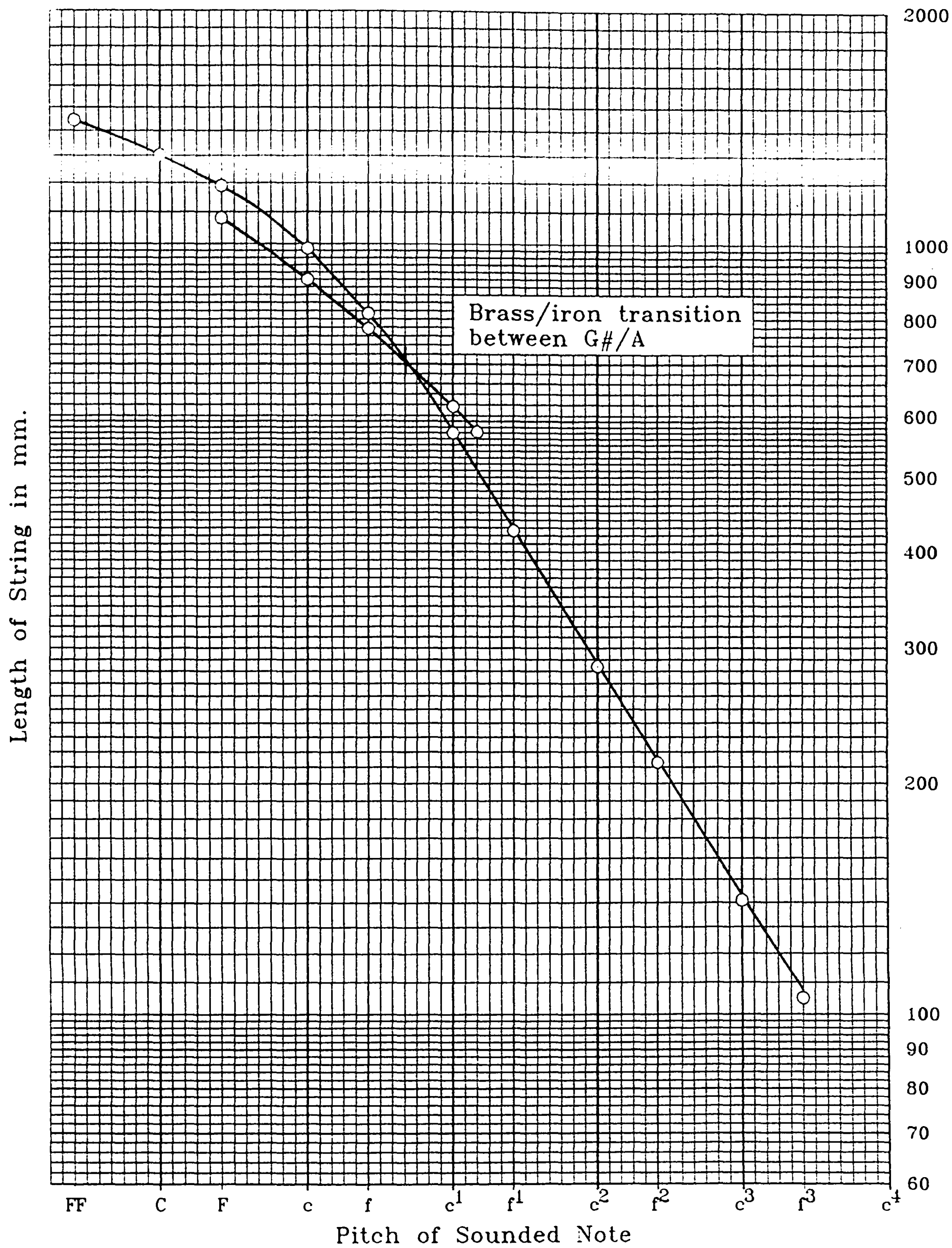
**Graph 3.1**
**The string scalings of the 1728 HH**



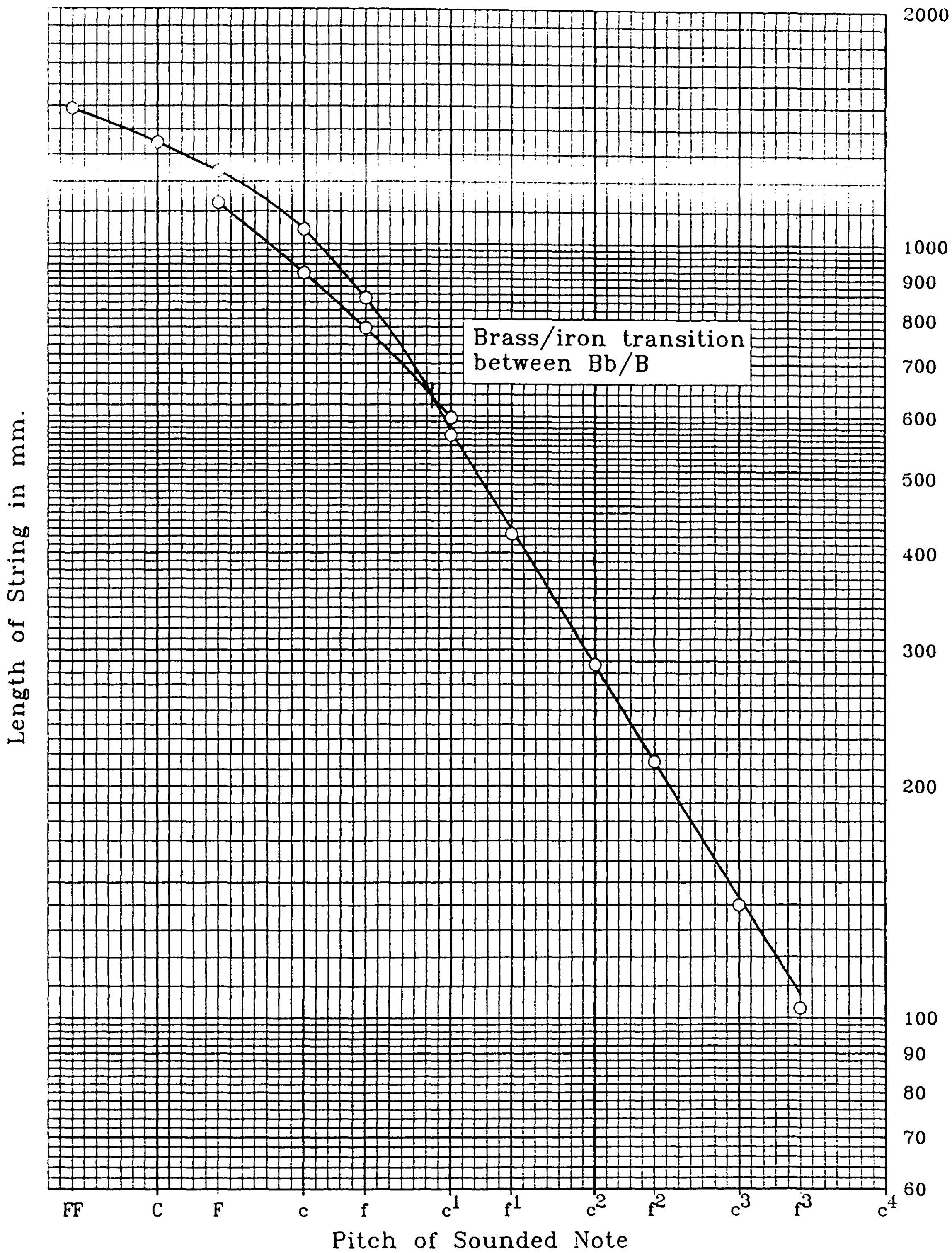
**Graph 3.2**
**The string scalings of the 1761b JH**



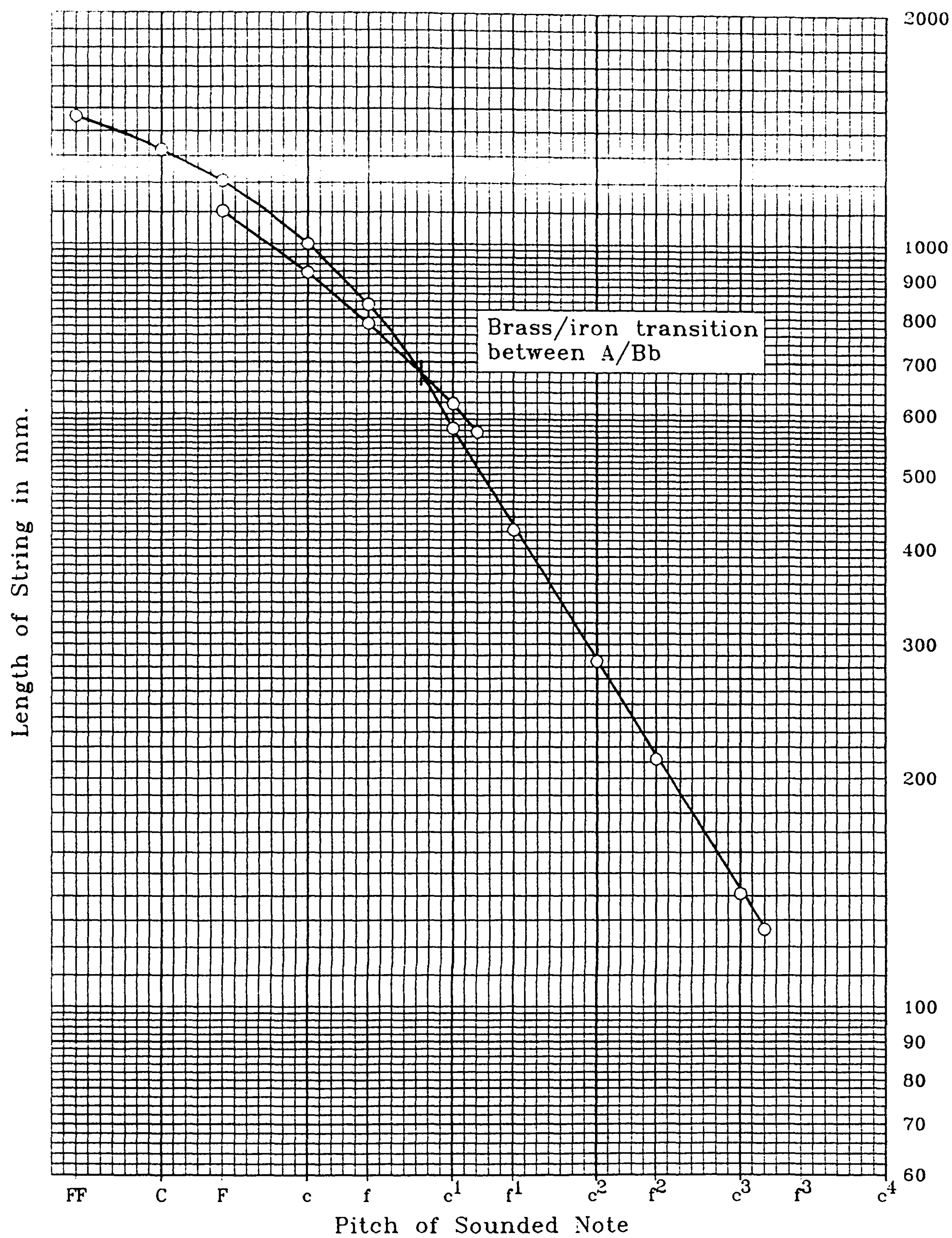
**Graph 3.3**
**The string scalings of the 1742a HH**



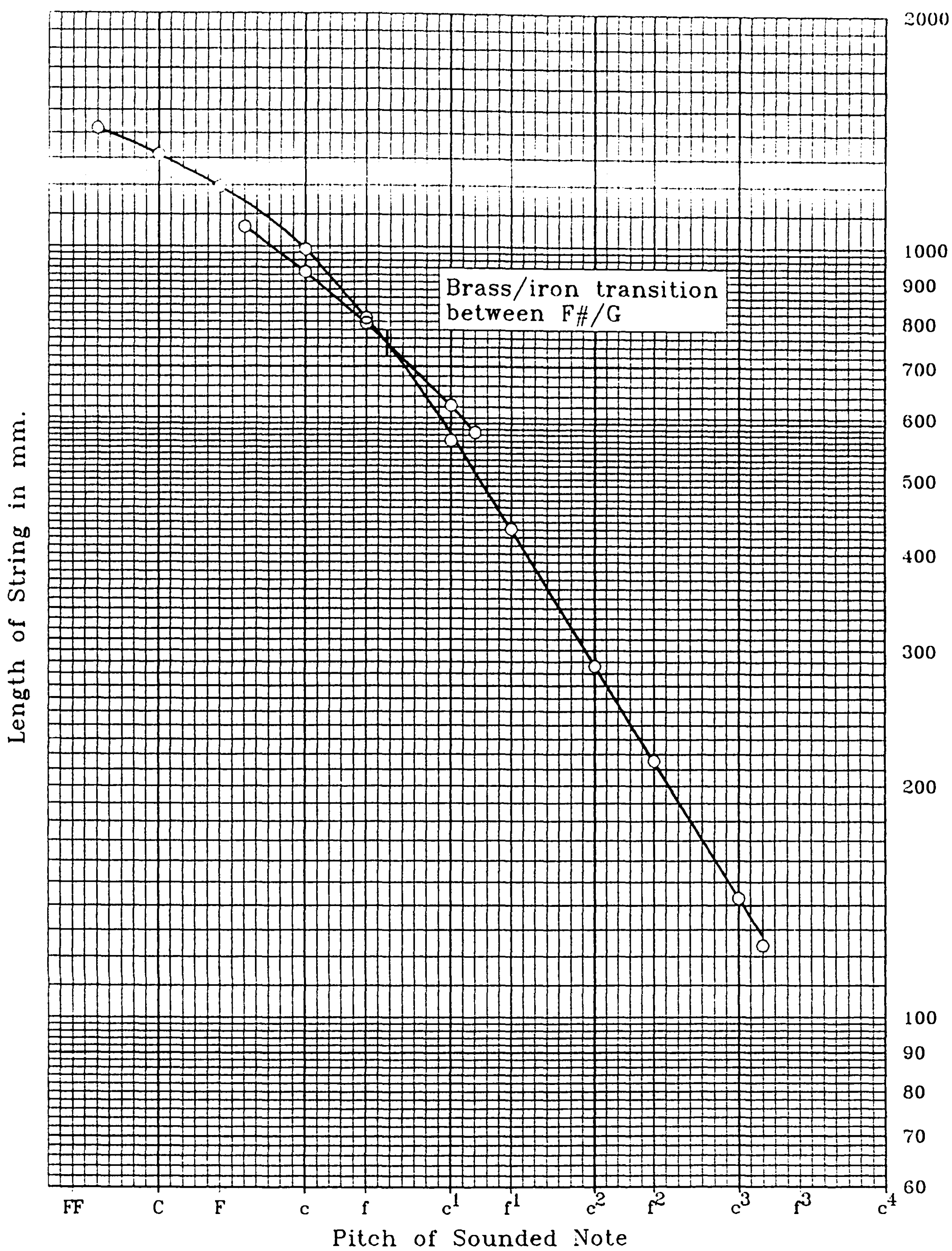
**Graph 3.4**
**The string scalings of the 1767 JH**



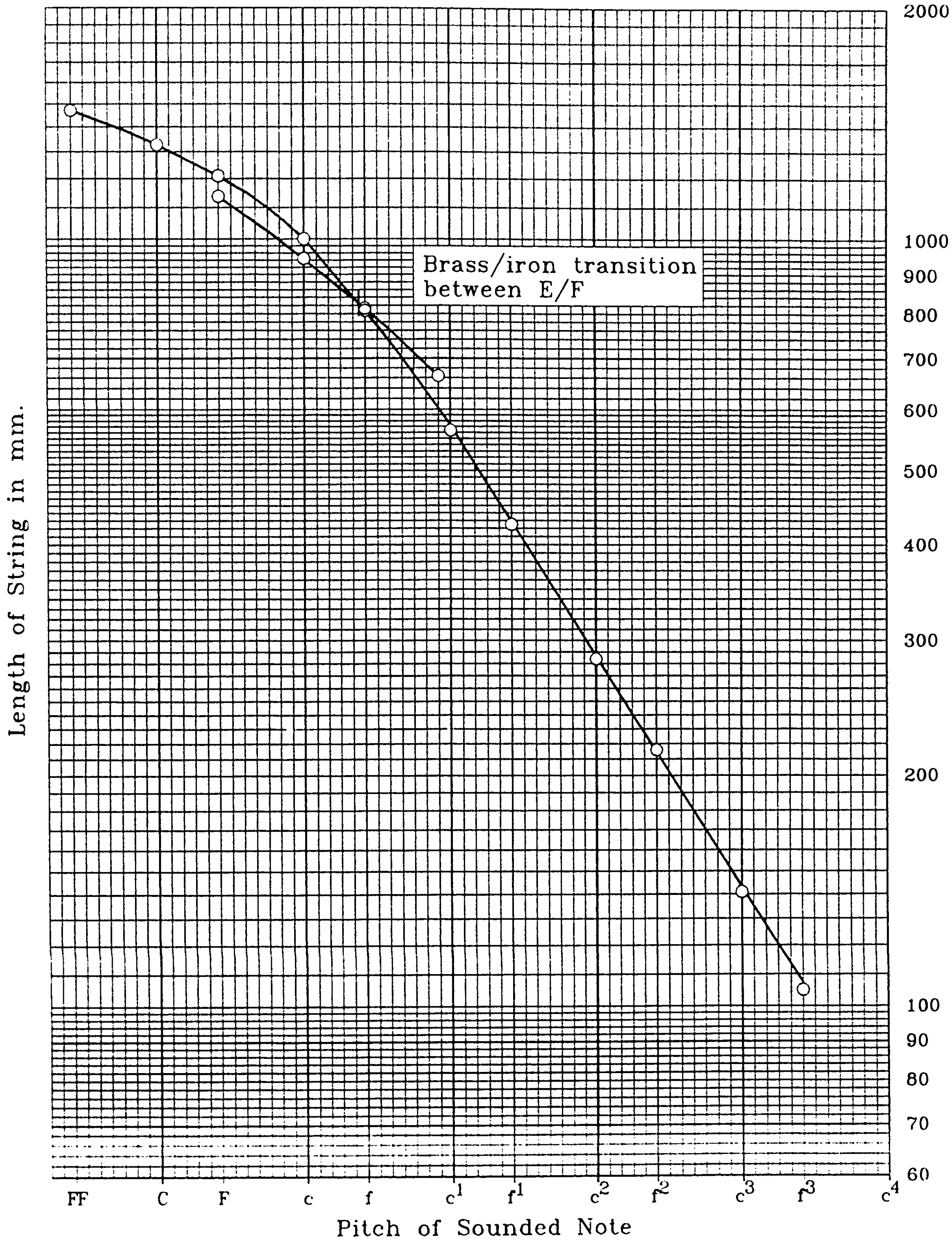
**Graph 3.5**
**The string scalings of the 1732b HH**



**Graph 3.6**
**The string scalings of the 1748 JH**



**Graph 3.7**
**The string scalings of the 1761a JH**



**The 8ft stringing material**

Both the stringing material and its gauge are fundamental to an instrument's tone quality, since in order to produce a set of partials whose frequencies correspond as closely as possible to those of a harmonic series the string has to be as long, thin and flexible as possible and just below its breaking point. Brass and iron, the two basic stringing materials used by the historical instrument maker, are of different densities and stiffness. Because brass is weaker than iron a shorter brass string is required to produce a note of the same pitch as an iron string. This is especially relevant in the bass where, in conjunction with a foreshortening of the strings, the use of brass strings can help avoid an excessively long instrument. During the time of the Hass family wire was produced by drawing rods of metal through a tapered hole in a dieplate, and as the wire was drawn it became work hardened. Since a thinner wire had to be drawn through a larger number of successively smaller dies than a thicker wire it was therefore both harder and stronger.[16] This means that the very highest treble strings can in fact withstand a slightly longer equivalent $c^2$ scaling than average without breaking.

Grant O'Brien has shown that a careful analysis of a harpsichord's string lengths can determine its stringing material. He has shown that a plucked keyboard instrument with a $c^2$ scaling of approximately 285mm was designed to be strung with brass strings throughout the compass, whereas one with a $c^2$ scaling of about 350mm was designed for brass strings in the bass and tenor sections only, and when the equivalent $c^2$ scaling of 285mm was exceeded there was a transition to stronger iron scalings to avoid string breakage.[17] The mean $c^2$ scaling of Hass clavichords of 286.2mm is very similar to O'Brien's calculated yellow brass scaling for Ruckers'

[16] M. Goodway and J. Odell, "The metallurgy of 17th- and 18th-century music wire," in *The Historical Harpsichord*, ed. H. Schott, 3 vols. (Stuyvesant, New York: Pendragon Press, 1984), 2:51-84.

clavecimbles of 289.5mm and Taskin's harpsichords of 292.6mm,[18] and since the $c^2$ equivalent scaling is not exceeded this implies the use of yellow brass as a stringing material for all the 8ft strings.

**The 4ft stringing material**

Since the 4ft bridge is straight the string lengths are not at all Pythagorean. Moreover since the top seven or eight notes of the 4ft usually exceed the nominal $c^2$ length of 286.49mm - by between 28mm and 50mm for the highest note d of the 1746 JH and 1760b JH respectively - a transition from brass to iron stringing is needed to avoid string breakage.[19] Both graphical analysis (in graphs 3.1 to 3.7) and measurements of all the 4ft string lengths in the case of the 1740b HH (see table 3.8) have shown that the brass/iron transition occurs at different points: either between E and F, $F^{\#}$ and G, $G^{\#}$ and A, A and $B^b$ or between the notes $B^b$ and B. It is possible, however, that these variations are unintentional and the result of slight differences in both the positioning of the 4ft bridge and in the marking-out of the position of the 4ft bridge pins. Hass may in fact have always made the brass/iron transition between the same two notes, perhaps between G and $G^{\#}$.

Both the concept of the transition from brass to iron stringing and its occurence between G and $G^{\#}$ is confirmed by the survival of some old, possibly eighteenth-century strings and their remnants on one Hass and one Gerlach clavichord. The

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[17] G. O'Brien, "The Stringing and pitches of Ruckers instruments," *Colloquium: Ruckers Klavecimbels en Copieën* (Antwerp, 1977), pp.48-71; G. O'Brien, "Some principles of eighteenth century harpsichord stringing and their application," *The Organ Yearbook*, XII (1981), pp.160-76.

[18] G. O'Brien, "The Stringing and pitches of Ruckers instruments," *Colloquium: Ruckers Klavecimbels en Copieën* (Antwerp, 1977), p.67.

[19] See G. O'Brien, "Case Study: An unfretted Clavichord by I.C. Gerlach, Hamburg, 1756, or what can be learned by not restoring," paper given at Antwerp (Edinburgh, 1991), p.5.

1760b JH has some old-looking 4ft strings with very neatly made loops and coils of brass for the notes FF to G, and of iron for G# to d; and the clavichord made in Hamburg by Johann Gerlach in 1756 has old, although probably not original, brass coils on the 4ft tuning pins for the notes FF to F, with the coils for the notes FF#, BB$^{b}$, F# and G missing, and iron coils for the notes G# to c#, with the coil for the note d missing. The concept of the brass/iron transition is also confirmed by an anonymous clavichord at the Germanisches Nationalmuseum in Nürnberg, museum number MINe 73, which has the words *gelb* (literally yellow, indicating brass) and *weiss* (literally white, indicating iron) marked on the soundboard next to the 4ft bridge at the note F.[20] Unfortunately because the bridges have been removed, the string scalings of this instrument cannot be measured in order to see if the theoretical brass/iron transition occurs at the note F.

Although the highest note with a 4ft string is usually d, the octave strings of six late Johann Hass clavichords extend only to the note c (in the case of the 1761c JH and the 1767 JH) or to the note B (in the case of the 1761a JH, the 1762 JH, the 1763a JH and the 1763b JH). Furthermore it is only the top two or three notes of the 4ft register of these later instruments which exceed the nominal $c^2$ equivalent length of 286.49mm: the top 4ft note B, for example, on the 1763a JH has an equivalent $c^2$ length of 295mm (see table 3.8), which is very close to the actual $c^2$ scaling of 291mm of the 1728 HH. This may mean that in his later instruments Johann Hass strung all the 4ft notes in brass. Indeed, the top two or three brass 4ft strings are able to withstand a slightly longer equivalent $c^2$ length because these strings are work-hardened. Stringing the 4ft in brass and iron must have created tuning problems for Hass: since iron has a different expansion coefficient from

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[20] F. Hellwig, "Strings and Stringing: Contemporary Documents," *The Galpin Society Journal*, XXIX (1976), p.93.

brass the few iron strings would have gone out of tune relative to the rest of the instrument.

**Table 3.8**
**4ft scalings and theoretical materials of the 1740b HH and the 1763a JH**

**1740b HH**

| | Length (mm) | $c^2$ Equivalent | Stringing Material |
|---|---|---|---|
| d | 577 | 323.8 | Iron |
| $c^{\#}$ | 604 | 320.0 | |
| c | 630 | 315.0 | |
| B | 652 | 307.7 | |
| $B^{b}$ | 675 | 300.7 | |
| A | 700½ | 294.5 | |
| $G^{\#}$ | 725 | 287.7 | Iron |
| G | 753 | 282.1 | Brass |
| $F^{\#}$ | 778 | 275.1 | |
| F | 802½ | 267.8 | |
| E | 830 | 261.4 | |
| $E^{b}$ | 857 | 254.8 | |
| D | 882 | 247.5 | |
| $C^{\#}$ | 910 | 241.0 | |
| C | 936 | 234.0 | Brass |

**1763a JH**

| | Length (mm) | $c^2$ Equivalent | Stringing Material |
|---|---|---|---|
| B | 625 | 295.0 | Brass |
| $B^{b}$ | 647½ | 288.4 | |
| A | 673 | 283.0 | |
| $G^{\#}$ | 700 | 277.8 | |
| G | 724½ | 271.4 | |
| $F^{\#}$ | 750 | 265.2 | |
| F | 782 | 261.0 | |
| E | 804 | 253.2 | |
| $E^{b}$ | 832½ | 247.5 | |
| D | 859 | 241.0 | |
| $C^{\#}$ | 886½ | 234.8 | |
| C | 914 | 228.5 | |
| BB | 942 | 222.3 | |
| $BB^{b}$ | 970 | 216.0 | |
| AA | 997 | 209.6 | |
| $GG^{\#}$ | 1027 | 203.8 | |
| GG | 1054 | 197.4 | |
| $FF^{\#}$ | 1086 | 192.0 | |
| FF | 1116 | 186.2 | Brass |

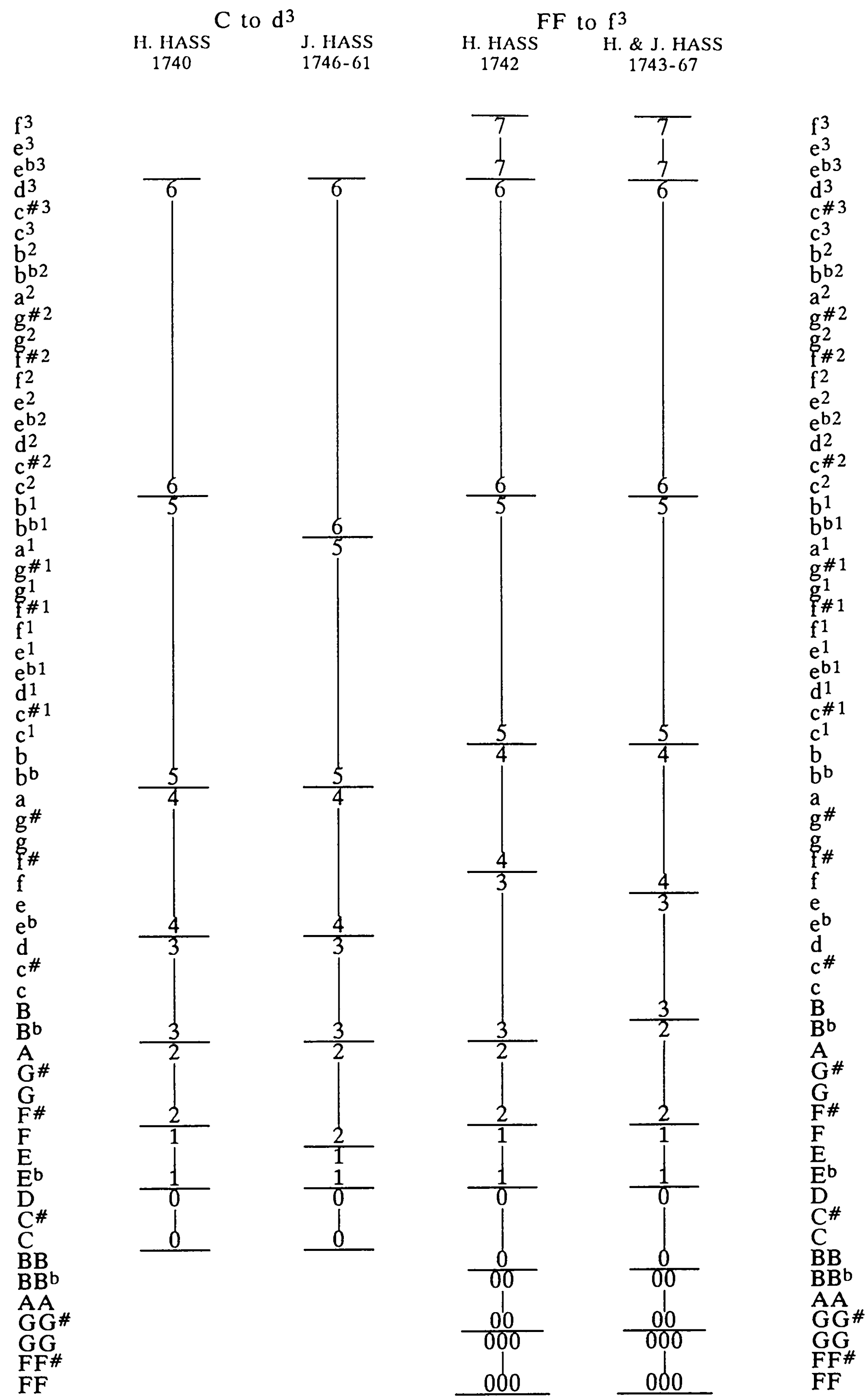
**The Hamburg gauge system**

As well as determing the correct stringing material, it is also important to quantify the correct string gauge. Owing to the inefficiency of the soundboard in the bass, the only way to maintain the tension of the bass strings and prevent them from sounding weak and feeble is to increase the mass per unit length and therefore the string diameter. Both Hieronymus and Johann Hass always marked the 8ft string gauge numbers and the note names on the soundboard, usually in black ink, beside every pair of 8ft tuning pins. The numbers range from 0, 00 or 000 in the bass to either 6 or 7 in the treble. The 8ft gauge numbers marked by father and son on the soundboards of their standard C to $d^3$ models (see table 3.9) vary only slightly in the treble: whereas gauge 5 is marked from $b^b$ to $b^1$ and gauge 6 from $c^2$ to $d^3$ on the two Hieronymus Hass clavichords dating from 1740, gauge 5 is marked from $b^b$ to a and gauge 6 from $b^b$ to $d^3$ on Johann Hass clavichords. All FF to $f^3$ instruments from 1743 onwards, except the unique trichord-strung 1761a JH, have the same gauge markings as given in table 3.9. Both the surviving 1742 clavichords vary from the usual gauge markings for the FF to $f^3$ models in that gauge 3 is marked from $B^b$ to f instead of B to e, and gauge 4 is marked from $f^\#$ to b, instead of f to b.

Only a few gauge numbers are legible on the soundboard of the GG to $d^3$ 1748 JH (see table 3.10), but those remaining are the same as those of the standard FF to $f^3$ models. The gauge numbers of the FF to $d^3$ 1732b HH are marked beside exactly the same notes as the standard FF to $f^3$ models for gauges 2, 3, 4 and 5 only. Elsewhere the intended stringing is lighter: whereas on standard five-octave models gauge 6 is marked from $c^2$ to $d^3$, gauge 6 is marked from $c^2$ to $a^2$ on the 1732b HH and gauge 7 is marked from $b^{b2}$ to $d^3$. Similarly in the bass, whereas on standard five-octave models gauge 000 is marked from FF to GG, gauge 00 from $GG^\#$ to $BB^b$, gauge 0 from BB to D and gauge 1 from $E^b$ to F, gauge 00 is marked from FF to GG on the 1732b HH, gauge 0 from $GG^\#$ to C and gauge 1 from $C^\#$ to F. Corroboration of these gauge numbers is met by the (1725) HH, since although only the top two octaves of gauge numbers are legible on this instrument they are identical to those found on the 1732b HH. This probably indicates that early Hieronymus Hass clavichords were designed for a lighter treble stringing than that found on instruments after 1740. Unfortunately, it is not known if the 1728 HH was also designed for this lighter stringing, since none of the gauge numbers is legible.

**Table 3.9**
**Hass 8ft gauge markings**

**Standard models**



## Table 3.10
## Hass 8ft gauge markings

### Unique models

| | C to d³ (1725) HH | FF to d³ 1732b HH | GG to d³ 1748 JH | FF to f³ 1761a JH | |
|---|---|---|---|---|---|
| f3 | | | | 7 | f#3 |
| e3 | | | | | e3 |
| eb3 | | | | 7 | eb3 |
| d3 | 7 | 7 | ? | 6 | d3 |
| c#3 | | | | | c#3 |
| c3 | | | | | c3 |
| b2 | | | | | b2 |
| bb2 | 7 | 7 | | | bb2 |
| a2 | 6 | 6 | | | a2 |
| g#2 | | | 6 | | g#2 |
| g2 | | | | 6 | g2 |
| f#2 | | | | 5 | f#2 |
| f2 | | | | | f2 |
| e2 | | | | | e2 |
| eb2 | | | 6 | | eb2 |
| d2 | | | | | d2 |
| c#2 | | | | | c#2 |
| c2 | 6 | 6 | | | c2 |
| b1 | 5 | 5 | ? | | b1 |
| bb1 | | | | | bb1 |
| a1 | | | | | a1 |
| g#1 | | | | | g#1 |
| g1 | | | | | g1 |
| f#1 | | | | | f#1 |
| f1 | | | 5 | | f1 |
| e1 | | | | | e1 |
| eb1 | | | | | eb1 |
| d1 | | | | | d1 |
| c#1 | | | | | c#1 |
| c1 | 5 | 5 | 5 | 5 | c1 |
| b | 4 | 4 | 4 | 4 | b |
| bb | | | | | bb |
| a | | | | | a |
| g# | | | | | g# |
| g | | | | | g |
| f# | ? | | | | f# |
| f | | 4 | 4 | | f |
| e | | 3 | 3 | 4 | e |
| eb | | | | 3 | eb |
| d | | | | | d |
| c# | | | | | c# |
| c | | | | | c |
| B | | 3 | | | B |
| Bb | | 2 | | 3 | Bb |
| A | ? | | | 2 | A |
| G# | | | | | G# |
| G | | | | | G |
| F# | | 2 | ? | 2 | F# |
| F | | 1 | | 1 | F |
| E | | | | | E |
| Eb | | | | 1 | Eb |
| D | | | | 0 | D |
| C# | | 1 | | | C# |
| C | ? | 0 | | | C |
| BB | | | | | BB |
| BBb | | | | 0 | BBb |
| AA | | | | 00 | AA |
| GG# | | 0 | | 00 | GG# |
| GG | | 00 | ? | 000 | GG |
| FF# | | | | | FF# |
| FF | | 00 | | 000 | FF |

There are no known Hamburg-made clavichords or harpsichords with a complete set of original eighteenth-century strings. At least two Hass clavichords, the 1743b HH and the 1760b JH, have a small number of old 8ft strings, but these are not enough to calculate the entire Hamburg gauge system with any degree of certainty. Six numbered spools of brass wire survive with the baryton viol made in Hamburg in 1686 by Tielke and now preserved in the Victoria and Albert Museum, London, inventory number 115-1865, but these are neither consistent within themselves nor with the few old strings found on the two Hass clavichords. Grant O'Brien has, however, shown in a recent paper given at the International Clavichord Conference at Magnano, Italy, that keyboard instrument makers working throughout Northwestern Europe in the eighteenth century all used the same gauge system.[21] O'Brien provided clear evidence that the Nuremburg, Swedish, French, English (with the numbering reversed) and the Hamburg Gauge Systems were all the same, that each system had a drawing ratio ($r_d$) close to 5/4, and that the wire used in each of these systems probably came from Nuremburg. Consequently, any one of these systems could be used to string a clavichord built by either member of the Hass family.

Table 3.11 gives the string gauges found on an anonymous North- or Central-German clavichord of about 1750 in the Gesellschaft der Musikfreunde in Vienna,[22] the Berlin/Nuremburg System reported by Michael Thomas[23] and the measurements

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[21] G. O'Brien, "Stringing Materials and Gauges for Clavichords by I.C. Gerlach and H.A. and J.A. Hass," paper given at Magnano International Clavichord Symposium (Edinburgh, September, 1993), pp.6-8.

[22] A. Huber, "Überlegungen zur Besaitung eines Clavichordes von H.A. Haas, Hamburg 1732," *Arbeitsblätter für Restauratoren*, 2/92 (1992), pp.144-53.

[23] M. Thomas, "String Gauges of Old Italian Harpsichords," *The Galpin Socity Journal*, XXIV (1971), p.78.

of the few old strings I have found on the 1743b HH and the 1760b JH. The smaller gauges of the two Hass clavichords have been derived from the few measured diameters by fitting the measurements to a straight line, and then multiplying the derived mean value by the drawing ratio of 5/4.

**Table 3.11**
**The Hamburg gauge system**

| Gauge Number | Whitehead H. Hass 1743b | | Whitehead J. Hass 1760b | | Thomas Berlin / Nuremburg | | Huber Anonymous c.1750 | | Gauge Number |
|---|---|---|---|---|---|---|---|---|---|
| | Meas. | Fitted | Meas. | Fitted | Meas. | Fitted | Meas. | Fitted | |
| 10 | --- | (0.184) | --- | (0.189) | --- | (0.101) | --- | (0.189) | 10 |
| 9 | --- | (0.206) | --- | (0.211) | --- | (0.145) | --- | (0.211) | 9 |
| 8 | --- | (0.230) | --- | (0.235) | --- | (0.197) | --- | (0.237) | 8 |
| 7 | --- | (0.257) | --- | (0.263) | --- | (0.245) | [0.28] | (0.265) | 7 |
| 6 | --- | (0.287) | --- | (0.294) | 0.31 | 0.293 | 0.30 | 0.296 | 6 |
| 5 | --- | (0.321) | --- | (0.329) | 0.34 | 0.340 | 0.315 | 0.332 | 5 |
| 4 | --- | (0.359) | --- | (0.368) | 0.38 | 0.388 | 0.36 | 0.371 | 4 |
| 3 | --- | (0.402) | 0.41 | 0.411 | 0.42 | 0.436 | 0.41 | 0.416 | 3 |
| 2 | --- | (0.449) | 0.47 | 0.460 | 0.47 | 0.484 | 0.455 | 0.465 | 2 |
| 1 | 0.510 | 0.502 | --- | (0.514) | 0.54 | 0.532 | [0.54] | (0.520) | 1 |
| 0 | --- | (0.561) | --- | (0.575) | 0.59 | 0.580 | 0.57 | 0.583 | 0 |
| 00 | [0.624] | (0.627) | [0.63] | (0.642) | 0.63 | 0.628 | 0.675 | 0.652 | 00 |
| 000 | [0.694] | (0.701) | --- | (0.718) | --- | (0.675) | --- | (0.730) | 000 |
| $r_g$ | (1.11803) | | (1.11803) | | 1.11283 | | 1.11921 | | |
| $r_d$ | (1.25) | | (1.25) | | 1.2384 | | 1.25263 | | |

**The determination of the 4ft string gauges**

Unfortunately there are no Hass clavichords, or indeed any Hamburg-made clavichord with 4ft gauge markings. Only one Hamburg-made clavichord, the 1756 JG, has enough old string fragments on the 4ft tuning pins from which it would be possible to draw up a stringing list, but these are not measurable without causing irreparable damage to the remnants themselves.

The 1751 unfretted clavichord built in Brunswick (a town within the sphere of influence of Hamburg) by Barthold Fritz and presently preserved in the Victoria and Albert Museum, London, inventory number 339-1882, does however have the 4ft string gauges indicated on the keylevers. Since the instrument is built very much in the Hamburg tradition, with similar 8ft scalings and gauge markings as those used by Hass, the 4ft gauge numbers can be used to help determine the 4ft gauges of Hass clavichords. First, the tension (T) for each 4ft string of the Fritz must be calculated using the formula:[24]

$$T = {}^{p\pi}/_{g} \cdot (fld)^2$$

where

T = string tension in kg
p = string material density
g = acceleration of gravity - 9.8 $^{m}/sec^2$
f = frequency in Hz
l = string length in metres
d = string diameter in metres
${}^{p\pi}/_{g}$ = 2639 for yellow brass (FF to G$^{\#}$), and 2463 for iron (A to c)

In order to calculate the string tensions it is necessary to know the pitch for which the clavichord was designed. Although the $c^2$ scaling of the 1751 Fritz clavichord is 294mm compared to a mean $c^2$ scaling of 286.2mm for Hass clavichords, the longer Fritz string scaling does not correspond to a lower pitch. Instead, the difference in string length is probably the result of the two makers using different local units of measure, since despite working in Brunswick, it appears that Fritz was using the Hanoverian Fuss[25] (equivalent to 292.1mm[26]) compared to the Hass family who

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24 G. O'Brien, "Some Principles of Eighteenth Century Harpsichord Stringing and their Application," *The Organ Yearbook*, XII (1981), pp.167-75.

25 K. Karmarsch, "Gewichte und Maße," *Technologische Enzyclopadie oder alphabetisches Handbuch der Technologie* (Stuttgart, 1833), pp.559-67.

were using the Hamburg Fuss (equivalent to 286.49mm). Consequently, the frequencies used for calculating the string tensions given in table 3.12 are based on A409 Hz. The 4ft gauges are those reported by Howard Schott[27] and the string diameters are the fitted average string measurements of the anonymous North- or Central-German clavichord as published by Alfons Huber and calculated by Grant O'Brien.[28]

**Table 3.12**
**1751 Fritz 4ft string scalings, materials and gauge numbers**
**(based on A409 Hz)**

| Notes | f in Hz | l in mm | $c^2$ equivalent scaling | Material | Gauge Number | d in mm | Calculated T in kg fitted |
|---|---|---|---|---|---|---|---|
| c | 243.2 | 652½ | 326.3 | Iron | 7 | .265 | 5.42 |
| B | 229.6 | 678 | 320.0 | | 6 | .296 | 5.39 |
| B$^b$ | 216.7 | 698 | 310.9 | | 6 | .296 | 5.36 |
| A | 204.5 | 723 | 304.0 | Iron | 5 | .332 | 5.34 |
| G$^\#$ | 193.0 | 742 | 294.5 | Brass | | | 5.31 |
| G | 182.2 | 764 | 286.2 | | | | 5.28 |
| F$^\#$ | 172.0 | 785 | 277.5 | | | | 5.26 |
| F | 162.3 | 810 | 270.3 | | 5 | .332 | 5.23 |
| E | 153.2 | 832 | 262.1 | | 4 | .371 | 5.20 |
| E$^b$ | 144.6 | 857 | 254.8 | | | | 5.17 |
| D | 136.5 | 878 | 246.4 | | | | 5.15 |
| C$^\#$ | 128.8 | 901 | 238.6 | | | | 5.12 |
| C | 121.5 | 926½ | 231.6 | | 4 | .371 | 5.09 |
| BB | 114.7 | 947 | 223.5 | | 3 | .416 | 5.07 |
| BB$^b$ | 108.3 | 975 | 217.2 | | | | 5.04 |
| AA | 102.2 | 1004 | 211.1 | | | | 5.01 |
| GG$^\#$ | 96.5 | 1027 | 203.8 | | 3 | .416 | 4.99 |
| GG | 91.1 | 1055 | 198.0 | | 2 | .465 | 4.96 |
| FF$^\#$ | 86.2 | 1080 | 190.9 | | | | 4.93 |
| FF | 81.2 | 1110 | 185.2 | Brass | 2 | .465 | 4.91 |

[26] Using the Hanoverian Zolle the case (without the mouldings) of the 1751 Fritz measures 72 Zolle long (nominally 1752.6mm, actually 1754½mm) by $22^1/_3$ Zolle wide (nominally 543.6mm, actually 543mm).

[27] H. Schott, *Catalogue of Musical Instruments, vol.1: Keyboard Instruments* (London: Her Majesty's Stationery Office, 1985), p.79.

[28] G. O'Brien, "Stringing Materials and Gauges for Clavichords by I.C. Gerlach and H.A. and J.A. Hass," paper given at Magnano International Clavichord Symposium (Edinburgh, September, 1993), p.7.

With the aid of the tensions for the 4ft strings of the 1751 Fritz clavichord, tables 3.13 and 3.14 show the calculation of the 4ft string diameters for the 1740b HH and the 1763a JH respectively. The calculations use the formula:

$$d = \frac{1}{fl} \cdot \left(\frac{T}{p\pi/g}\right)^{\frac{1}{2}}$$

**Table 3.13**
**Calculation of the 4ft string diameters of the 1763a JH**
**(based on A409 Hz)**

| Calculations for the 1763a JH | | | | | | | 1760b JH measurements. | |
|---|---|---|---|---|---|---|---|---|
| Notes | f in Hz | l in mm | T in kg | $p\pi/g$ | Calc. d in mm | Calc. gauge | Meas. d in mm | Gauge |
| B | 229.6 | 625 | 5.39 | 2639 | .315 | 5 | --- | ? |
| B$^b$ | 216.7 | 647½ | 5.36 | │ | .321 | │ | --- | |
| A | 204.5 | 673 | 5.34 | │ | .327 | │ | --- | |
| G# | 193.0 | 700 | 5.31 | │ | .332 | 5 | --- | |
| G | 182.2 | 724½ | 5.28 | │ | .339 | 4 | --- | ? |
| F# | 172.0 | 750 | 5.26 | │ | .346 | │ | --- | |
| F | 162.3 | 782 | 5.23 | │ | .351 | │ | --- | |
| E | 153.2 | 804 | 5.20 | │ | .360 | │ | 0.350 | 4 |
| E$^b$ | 144.6 | 832½ | 5.17 | │ | .368 | │ | --- | │ |
| D | 136.5 | 859 | 5.15 | │ | .377 | 4 | --- | │ |
| C# | 128.8 | 886½ | 5.12 | │ | .386 | 3 | 0.375 | │ |
| C | 121.5 | 914 | 5.09 | │ | .395 | │ | 0.378 | │ |
| BB | 114.7 | 942 | 5.07 | │ | .406 | │ | 0.380 | 4 |
| BB$^b$ | 108.3 | 970 | 5.04 | │ | .416 | 3 | 0.415 | 3 |
| AA | 102.2 | 997 | 5.01 | │ | .428 | 2 | 0.410 | │ |
| GG# | 96.50 | 1027 | 4.99 | │ | .439 | │ | 0.410 | 3 |
| GG | 91.10 | 1054 | 4.96 | │ | .452 | │ | 0.473 | 2 |
| FF# | 86.20 | 1086 | 4.93 | │ | .462 | │ | 0.485 | │ |
| FF | 81.20 | 1116 | 4.91 | 2639 | .476 | 2 | 0.478 | 2 |

**Table 3.14**
**Calculation of the 4ft string diameters of the 1740b HH**
**(based on A409 Hz)**

| Note | f in Hz | l in mm | T in kg | $p\pi/g$ | Calc. d in mm | Calc. Gauge |
|---|---|---|---|---|---|---|
| d | 273.0 | 577 | 5.47 | 2463 | .299 | 5 |
| c# | 257.6 | 604 | 5.44 | │ | .302 | │ |
| c | 243.2 | 630 | 5.42 | │ | .306 | │ |
| B | 229.6 | 652 | 5.39 | │ | .312 | │ |
| B♭ | 216.7 | 675 | 5.36 | │ | .319 | │ |
| A | 204.5 | 700½ | 5.34 | │ | .325 | │ |
| G# | 193.0 | 725 | 5.31 | 2463 | .332 | │ |
| G | 182.2 | 753 | 5.28 | 2639 | .326 | │ |
| F# | 172.0 | 778 | 5.26 | │ | .334 | 5 |
| F | 162.3 | 802½ | 5.23 | │ | .342 | 4 |
| E | 153.2 | 830 | 5.20 | │ | .349 | │ |
| E♭ | 144.6 | 857 | 5.17 | │ | .357 | │ |
| D | 136.5 | 882 | 5.15 | │ | .367 | │ |
| C# | 128.8 | 910 | 5.12 | │ | .375 | 4 |
| C | 121.5 | 936 | 5.09 | 2639 | .386 | 3 |

Weight is given to this method of determining the 4ft string gauges for the two Hass clavichords by the fact that the calculated diameters are similar to actual measurements of some old, although probably not original, 4ft strings on the 1760b JH. The measured diameters are given alongside the calculated diameters of the 1763a JH in table 3.13 for comparative purposes.

The historical practice, as described by Jakob Adlung (1699-1762) in his *Musica Mechanica Organoedi*,[29] however, appears to have been to string the 4ft notes with the same gauge as that for the 8ft notes of the same sounding pitch. In section §580 of *Musica Mechanica Organoedi*,[30] published in two volumes in 1768, Jakob

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29 J. Adlung, *Musica Mechanica Organoedi* (Berlin: Friedrich Wilhelm Birnstiel, 1768), pp.150-1.

30 I am very grateful to Alfons Huber for pointing out this reference out to me, and to Dr Marte Cowell for translating this section of Adlung.

Adlung states that:

Zuweilen macht man die Clavichordien dreychöricht. Dieß ist sonderlich unten vom C bis c gebräuchlich: oder wo ein Clavichord tiefer anfängt, z.E. im Contra F; so wird es auch bis dahin dreychöricht gemacht. Die dritte Seyte ist zuweilen den übrigen gleich, und im C dem Töne nach achtfüßig, zuweilen aber zieht man solche eine Oktave höher; folglich muß man schwächere Seyten nehmen, nachdeim das Clavichord lang ist. Die Mensur dieser Seyten anlangend; so giebt man ihnen die Länge, wie die Seyten haben, die von gleicher Dicke sind. So aber die Clavichordien lang sind, muß man ihnen einen besondern Steg geben. Aldann laufen sie über ihren Steg, nicht aber über den großen, sondern durch denselben, bis zu den Wirbeln. Z.E. wenn mein Clavichord kurz wäre, und ich wollte auf C, welches No.1. sonst hat, die Oktave ziehen; so sehe ich nach, was die Oktave c für eine Nr. hat. Das ist ben mir No. 4. Doch sehe ich wohl, daß bey c die Seyten nicht die ganze Länge haben: aber das C bekömmt die völlige Länge; also kann ich die No. 4. nicht schlechterdings hinziehen, sondern ich muß sie über einen besondern Steg laufen lassen, daß der klingende Theil kürzer werde, und so kurz als er bey c ist. (Der klingende Theil ist von der Tangente bis zum Stege.) Wenn ich aber No. 5 oder 6. genommen hätte; so würde ich fast des Steges nicht nöthig gehabt haben. Und wie man mit einem Clave verfährt, so man es auch mit dem andern.

Sometimes Clavichords are made with three choirs [of strings]. This is particularly common from C to c, or if a clavichord starts lower, for example at FF, it would be triple strung down to there. Sometimes the third string is the same as the others, with a C at 8ft pitch, sometimes it is tuned an octave higher for which one needs thinner strings, depending on the length of the clavichord. As regards the scale of these strings one gives them the length of those strings of the same thickness. Depending on the length of the instrument these may need a separate bridge. In this case they run over their own bridge and not over the main one, rather through it, to the tuning pins. For example, if my clavichord were short and I wanted to string the octave of C, which normally uses gauge No.1, then I would look to the gauge number of c. In my case this is No.4. However, I can see that the strings at c do not have their full length - but C has its full length, so I cannot string No.4, but must run it over a special bridge, so that the sounding part be shorter, and of the length it has at c. (The sounding part is from the tangent to the bridge). If I had taken No.5 or 6 I almost wouldn't have needed the bridge. And as one does with one key [note], so also with the others.

Adlung's account of eighteenth-century clavichord stringing practice is an extremely important insight into the workings of an historical clavichord maker. If the 4ft notes of Hass clavichords were intended to be strung with the same thickness of wire as the 8ft strings an octave higher, this explains why both Hieronymus and Johann Hass (as well as Johann Gerlach and Johann Fleischer) did not consider it necessary to mark the 4ft gauges. Indeed, the similar tensions of the 4ft and 8ft strings of two Hass clavichords, the 1740b HH and the 1763a JH, calculated using Adlung's principle in tables 3.15 and 3.16 respectively shows that this is the most likely method used by Hieronymus and Johann Hass to string the 4ft notes of their clavichords.

**Table 3.15**
**A comparison of the 4ft and 8ft string tensions using Adlung's stringing principle for the 1740b HH**

| | 4ft strings | | | 8ft strings | | | |
|---|---|---|---|---|---|---|---|
| Note | l in mm | Adlung gauges | T in kg | T in kg | 8ft gauges | l in mm | Note |
| d | 577 | 5 | 6.74 | 5.75 | 5 | 515 | $d^1$ |
| $c^\#$ | 604 | | 6.57 | | | | |
| c | 630 | | 6.37 | 5.67 | | 574 | $c$-$c^\#$ |
| B | 652 | | 6.08 | | | | |
| $B^b$ | 675 | 5 | 5.81 | 5.56 | 5 | 638 | $b^b$-b |
| A | 700½ | 4 | 6.96 | 6.94 | 4 | 676 | a |
| $G^\#$ | 725 | | 6.64 | | | | |
| G | 753 | | 6.84 | 6.73 | | 747 | $g$-$g^\#$ |
| $F^\#$ | 778 | | 6.50 | | | | |
| F | 802½ | | 6.16 | 6.51 | | 825 | $f$-$f^\#$ |
| E | 830 | | 5.87 | | | | |
| $E^b$ | 857 | 4 | 5.58 | 6.12 | 4 | 897½ | $e^b$-e |
| D | 882 | 3 | 6.62 | 7.44 | 3 | 935 | d |
| $C^\#$ | 910 | | 6.27 | 7.19 | | 974 | $c^\#$ |
| C | 936 | 3 | 5.91 | 6.91 | 3 | 1012½ | c |

**Table 3.16**
**A comparison of the 4ft and 8ft string tensions using Adlung's stringing principle for the 1763a JH**

| | 4ft strings | | | 8ft strings | | | |
|---|---|---|---|---|---|---|---|
| Note | l in mm | Adlung gauges | T in kg | T in kg | 8ft gauges | l in mm | Note |
| B | 625 | 4 | 7.48 | 6.94 | 4 | 602 | b |
| B$^b$ | 647½ | \| | 7.15 | 6.99 | \| | 640 | b$^b$ |
| A | 673 | \| | 6.88 | 7.00 | \| | 679 | a |
| G# | 700 | \| | 6.63 | 6.92 | \| | 715 | g# |
| G | 724½ | \| | 6.33 | 6.93 | \| | 758 | g |
| F# | 750 | \| | 6.04 | 6.81 | \| | 796 | f# |
| F | 782 | 4 | 5.85 | 6.70 | 4 | 837 | f |
| E | 804 | 3 | 6.93 | 8.21 | 3 | 875 | e |
| E$^b$ | 832½ | \| | 6.62 | 7.96 | \| | 913 | e$^b$ |
| D | 859 | \| | 6.28 | 7.71 | \| | 952 | d |
| C# | 886½ | \| | 5.95 | 7.40 | \| | 988 | c# |
| C | 914 | \| | 5.63 | 7.03 | \| | 1021 | c |
| BB | 942 | 3 | 5.33 | 6.65 | 3 | 1052 | B |
| BB$^b$ | 970 | 2 | 6.30 | 7.82 | 2 | 1081 | B$^b$ |
| AA | 997 | \| | 5.92 | 7.34 | \| | 1110 | A |
| GG# | 1027 | \| | 5.60 | 6.88 | \| | 1138 | G# |
| GG | 1054 | \| | 5.26 | 6.42 | \| | 1164 | G |
| FF# | 1086 | 2 | 5.00 | 5.97 | 2 | 1187 | F# |
| FF | 1116 | 1 | 5.86 | 6.93 | 1 | 1214 | F |

Assuming that it was standard practice to string the notes of the 4ft with the same gauge of wire as that for the 8ft notes of the same pitch, the question then arises: why did Barthold Fritz consider it necessary to mark the 4ft wire gauges? The answer to this question is perhaps that Fritz desired that the notes of 4ft pitch should not be strung in the usual manner. Indeed, as table 3.17 shows, the 4ft string tensions calculated using the marked gauges are quite a lot lower than those determined from the marked 8ft gauges an octave higher because the strings are thinner. The thinner strings also mean that the notes of 4ft pitch are, in theory, quieter than those of Hass clavichords.

**Table 3.17**
**A comparison of the 4ft string tensions using the marked gauges and Adlung's stringing principle for the 1751 Fritz**

| Note | f in Hz | l in mm | $p\pi/g$ | marked gauges | T in kg (fitted) | Adlung gauges | T in kg (fitted) |
|---|---|---|---|---|---|---|---|
| c | 243.2 | 652½ | 2463 | 7 | 5.42 | 5 | 7.44 |
| B | 229.6 | 678 | \| | 6 | 5.39 | 4 | 7.35 |
| $B^b$ | 216.7 | 698 | \| | 6 | 5.36 | \| | 7.26 |
| A | 204.5 | 723 | 2463 | 5 | 5.34 | \| | 7.17 |
| $G^\#$ | 193.0 | 742 | 2639 | \| | 5.31 | \| | 7.08 |
| G | 182.2 | 764 | \| | \| | 5.28 | \| | 6.99 |
| $F^\#$ | 172.0 | 785 | \| | \| | 5.26 | \| | 6.90 |
| F | 162.3 | 810 | \| | 5 | 5.23 | 4 | 6.81 |
| E | 153.2 | 832 | \| | 4 | 5.20 | 3 | 6.72 |
| $E^b$ | 144.6 | 857 | \| | \| | 5.17 | \| | 6.62 |
| D | 136.5 | 878 | \| | \| | 5.15 | \| | 6.53 |
| $C^\#$ | 128.8 | 901 | \| | \| | 5.12 | \| | 6.44 |
| C | 121.5 | 926½ | \| | 4 | 5.09 | \| | 6.35 |
| BB | 114.7 | 947 | \| | 3 | 5.07 | 3 | 6.26 |
| $BB^b$ | 108.3 | 975 | \| | \| | 5.04 | 2 | 6.17 |
| AA | 102.2 | 1004 | \| | \| | 5.01 | \| | 6.08 |
| $GG^\#$ | 96.5 | 1027 | \| | 3 | 4.99 | \| | 5.99 |
| GG | 91.1 | 1055 | \| | 2 | 4.96 | \| | 5.90 |
| $FF^\#$ | 86.2 | 1080 | \| | \| | 4.93 | 2 | 5.80 |
| FF | 81.2 | 1110 | 2639 | 2 | 4.91 | 1 | 5.71 |

## CONCLUSION

The Hass family were almost continually revising their basic clavichord design - making changes, for instance, to the case dimensions, stringing and fretting. It would be imprudent, however, to suggest that these changes were necessarily improvements to the design because we can never know for certain Hass's reasoning behind them. Thanks to the family's habit of dating their instruments we are able to follow the evolution of the design chronologically from 1728 to 1767. It is not only design elements which can be shown to change gradually, however, since some aspects of the construction of Hass clavichords also evolve.

# Chapter 4

# THE CONSTRUCTION OF HASS CLAVICHORDS

## INTRODUCTION

It is not known for certain whether or not Hieronymus and Johann Hass developed a particular clavichord design on paper before constructing it in the workshop. It was probably not necessary for either builder to make a drawing each time he decided to increase the length and width of the case. Other aspects of the design, however, such as the factors governing the string scalings (most importantly the rack-slot spacing pattern, the bridge shape and the bridge-pin spacing) are very complicated. Since these three main elements determine the scalings interdependently, with changes in the bridge shape being matched by changes in the rack-slot spacing pattern, their design probably was undertaken on paper.

Although the Hass family built clavichords with many different case dimensions and with at least four different compasses, the majority of their instruments are either of the C to $d^3$ or the FF to $f^3$ type. A plan view of the basic case structure of these two types, using the (1725) HH for the C to $d^3$ model and the 1763a JH for the FF to $f^3$ model, is given in figures 4.1 and 4.2 respectively. Despite differences in the size and the framing these two standard types are constructed in essentially the same manner and using the same basic materials. The sides of Hass clavichords, for example, are always made from the same wood type and the corners of the case are always secured with the same type of joint. The general soundboard layout is also always the same. Consequently, it is relatively easy to authenticate an instrument which has perhaps lost its original signature, or to discard an instrument wrongly attributed to the Hass family.

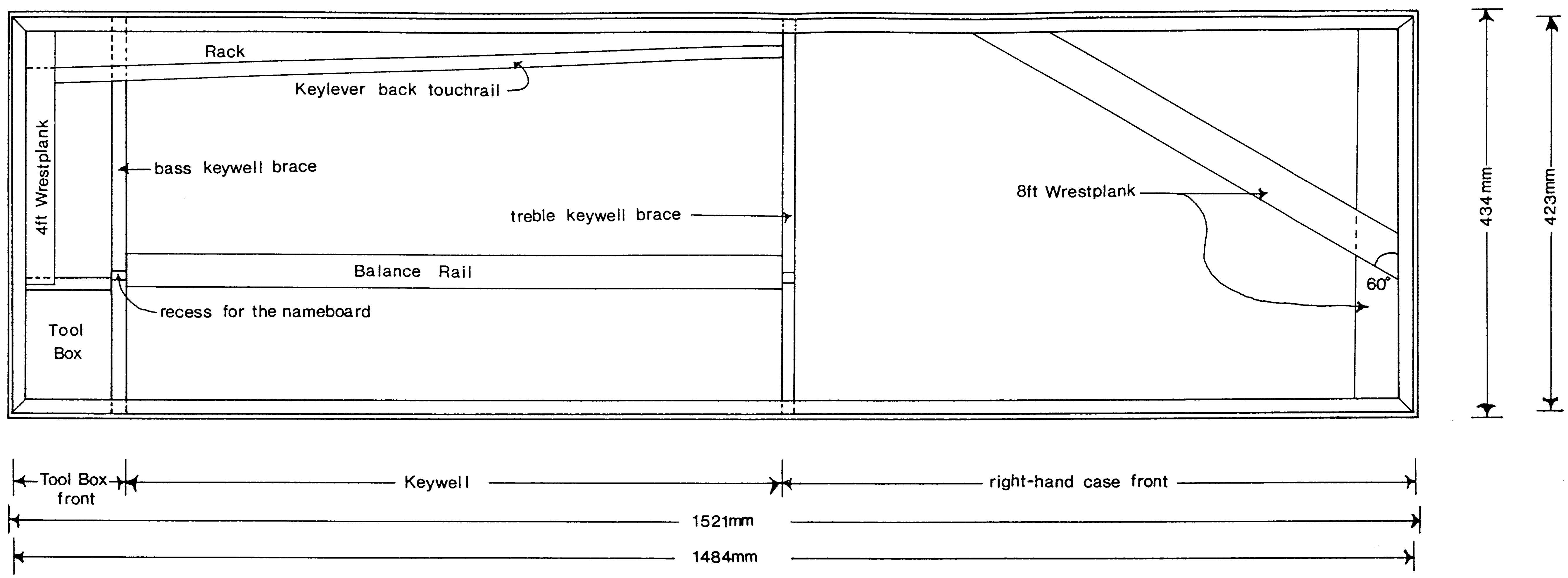


**Figure 4.1**
**Plan view of the C to $d^3$ model**
Scale 1:5

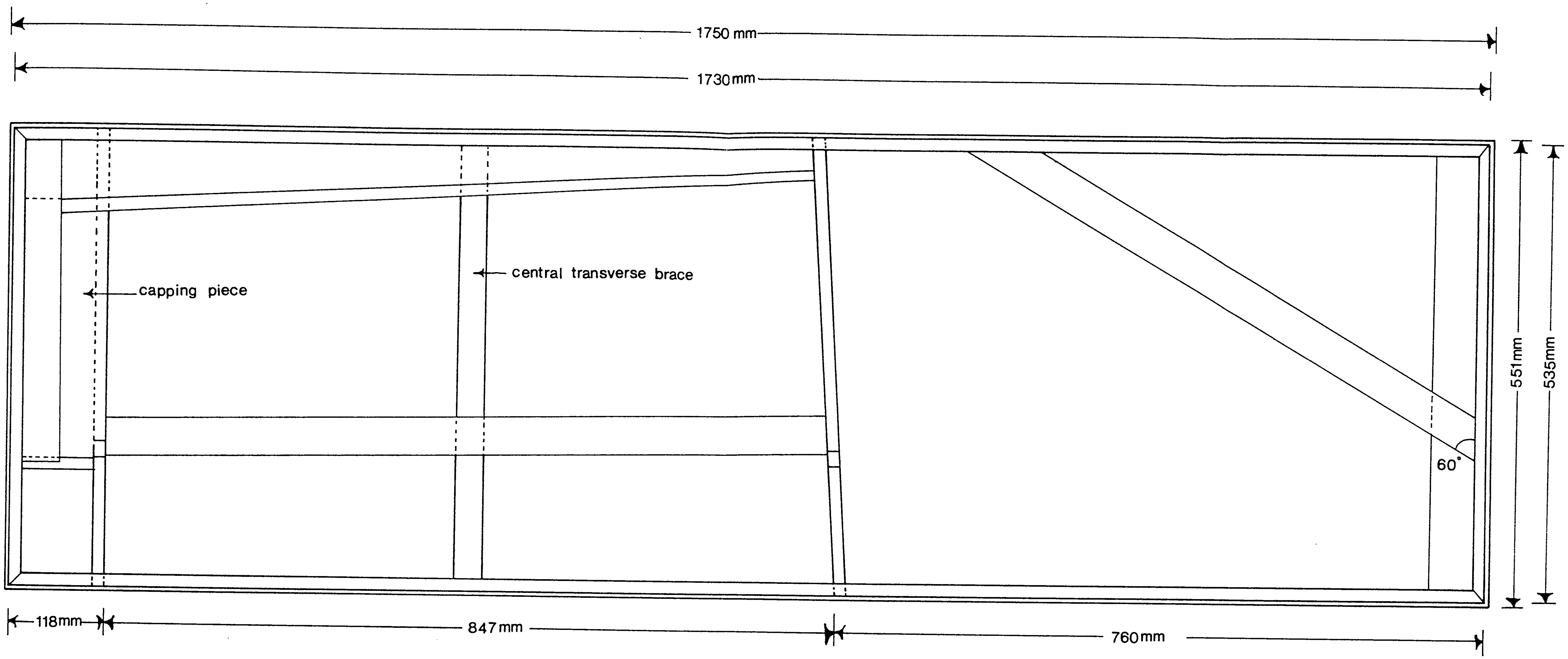


**Figure 4.2**
**Plan view of the FF to $f^3$ model**
Scale 1:5

As well as studying twenty-three of the extant clavichords, it was possible for me to gain an additional insight into the working methods of Hass by building a C to $d^3$ Hieronymus Hass-type clavichord. Although some mechanical tools were used (such as a bandsaw and electric planer) in the construction of the baseboard, case sides and lid, the soundboard, bridges and all of the case joints were made entirely by hand.

**THE BASEBOARD**

The baseboard of Hass clavichords is made from a red coniferous wood, probably Scots Pine. A small fragment from the baseboard of the 1763a JH was microscopically identified as belonging to the *Pinus* genus,[1] but from the anatomical structure alone it was not possible to indicate from which of the many possible species the sample was derived. Of the thirteen species described in *A Handbook of Softwoods*,[2] however, most can be discarded as woods likely to have been used by Hass since they occur in their natural state only in North and South America, Canada or Japan, and it is only *Pinus sylvestris* and *Pinus nigra* which are indigenous to North-West Europe. Since *P. nigra*, commonly known as Austrian Pine, is of low grade and generally used for rough work only, *P. sylvestris*, colloquially known as Scots Pine or Red Pine, would seem to be the most likely wood, because of the tree's widespread distribution throughout Europe. Although the best quality Scots pine (slowly grown in the more northerly latitudes) has relatively narrow bands of springwood which reduces the tendency for the wood to tear, the strong contrast between the spring and summer growth wood of Hass baseboards suggests that the

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[1] The work was carried out by the private wood anatomist Rowena Gale (in October, 1992) on the recommendation of the Pitt Rivers Laboratory, Cambridge University Museum of Archaeology and Anthropology.

[2] Ministry of Technology Forest Products Research Laboratory, *A Handbook of Softwoods* (London: Her Majesty's Stationary Office, 1957), pp.32-46.

timber was grown relatively quickly and therefore may have come from a local source.

The fundamental problem faced by any eighteenth-century clavichord builder is that of preventing the case from twisting under the tension and forces in the case, framing members and baseboard caused by the diagonal placement of the strings. The baseboard of Hass clavichords, which provides the basic strength of the instrument, is usually constructed from two planks of Scots Pine butt-jointed together along their length. Hass edge-jointed two planks of wood rather than using a single wide board because not only would a single wide board have been more expensive, but also more likely to warp than two narrower boards. Only the baseboard of the 1744a HH, constructed from three planks of Scots pine, differs from the otherwise standard practice of using two boards. It is possible that Hass used $1\frac{1}{4}$ Zolle-thick (nominally 29.8mm) planks for the baseboards of C to $d^3$ models and $1\frac{1}{2}$ Zolle-thick (nominally 35.8mm) planks for those of the five-octave FF to $f^3$ models. Baseboards of C to $d^3$ instruments vary in thickness from 25 to 28mm, whereas those of five-octave FF to $f^3$ instruments, which need to withstand a greater string tension, vary from 28 to 32mm thick. The small variability in baseboard thickness within each compass group may result from slight differences in the quality of the original timber used by Hass, and therefore in the amount of planing necessary to flatten a rough-sawn board of standard thickness. A badly-warped board may, for example, need more planing than one which is not twisted.[3]

Most Hass clavichords are characterised by a moulding cut directly into the baseboard along the length of the grain on the sides and across the endgrain at the ends. Although the moulding profile varies slightly on instruments made in differ-

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[3] This was suggested to me by Darryl Martin.

ent years, probably reflecting the re-sharpening of the moulding plane, the basic profile is the same for all clavichords built in the Hass workshops. The standard method of planing endgrain which avoids breaking out the corners, is to clamp a block of wood against the side of the piece being worked. Hass probably worked the moulding on the ends of the baseboard first and then worked the sides using two moulding planes whose blades were the mirror-image of each other, thereby enabling the moulding to be cut from both ends, from the right-hand end leftwards and from the left-hand end rightwards depending on the direction of the grain.

There are three clavichords, the 1732b HH, the 1740a HH and the 1742b HH, which do not have a moulding along the spine of the baseboard. Since the original decoration of all three of these instruments has been overpainted, it is difficult to be certain whether or not the absence of the spine moulding is an original feature of these three clavichords. Since the edge of the baseboard along the spine is flush with the back of the case, however, it is probable that the spine moulding has been planed off at some point in the instruments' history. Although there is the usual moulding along the front and spine of the baseboard of the (1725) HH, there is no moulding at all on the ends of the baseboard. Since both ends of the baseboard of the (1725) HH slightly overlap the case sides the absence, in this instance, of an end moulding may be an original feature. The baseboard of the 1743b HH differs from all other Hass clavichords in that it has an original applied moulding. This moulding is glued along the sides and ends of the baseboard and is mitred at each of the four corners. In all of these exceptional cases the moulding profile is the same as that of the standard instruments.

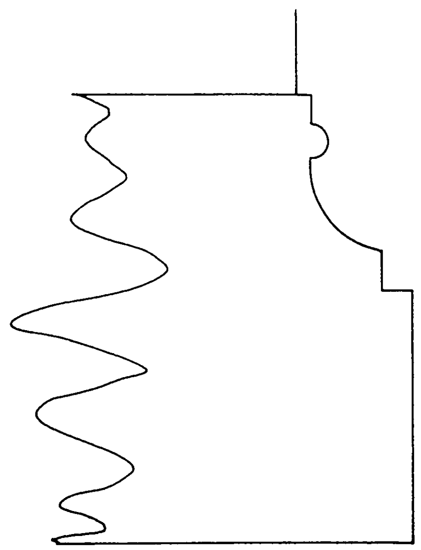


**Figure 4.3 Baseboard moulding profile in section**
Scale 2:1

## CASE SIDES, FRAMING MEMBERS AND SUPPORT BLOCKS

The case sides, framing members and support blocks of Hass clavichords are all made from the same red coniferous wood as that used for the baseboard, which is probably Scots Pine. As is usual with North European keyboard-instrument traditions the case and framing of Hass clavichords are assembled first and this structure is glued and dowelled to the upper surface of the baseboard. The four case sides are 14½ to 18½mm thick (nominally $^7/_{12}$ and $^9/_{12}$ Zoll respectively) and usually have an ogee or s-shaped moulding along the top edge, which must have been worked before the case was assembled.

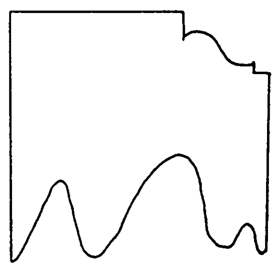
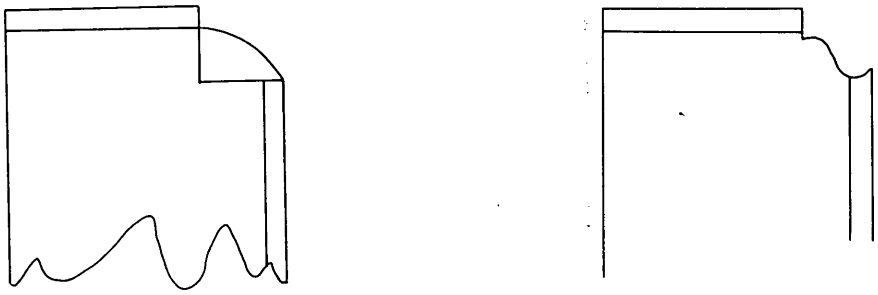


**Figure 4.4 Standard case moulding profile in section**
Scale 2:1

The case top of two late five-octave FF to $f^3$ clavichords, the 1763 JH and the 1767 JH differs from that of the majority of instruments. Along the top edge of the case, and inside the case above the soundboard, rack and 4ft wrestplank of both the 1763a JH and the 1767 JH is a veneer of olive wood and walnut respectively. The 1767 JH does have an ogee moulding worked into the top edge of the case, but this moulding has a slightly different profile than that found on standard instruments. In the case of the 1763a JH there is an added bead moulding, which appears to be made from a type of rosewood.



1763a JH 1767 JH

**Figure 4.5 Unique case moulding profile in section of the 1763a JH and the 1767 JH**
Scale 2:1

Due to the presence of the case top moulding each corner joint of the case is always in two sections: a main dovetail joint, the pins of which are spaced to take up most of the case height, and a small mitre joint at the top of the case for the moulding. Because the parts of each dovetail interlock the corner joints help prevent the case from twisting under the tension of the strings. It is interesting that the number of dovetails in each corner joint depends on the case height of the clavichord: the corners of C to $d^3$ instruments, with an average case height excluding the thickness of the baseboard of $4^3/_4$ Zolle (nominally 113.4mm, actually

112mm), have two full pins and two half pins (which are angled on one side only); whilst the case corners of FF to f$^3$ instruments, with a larger average case height of $5^3/_4$ Zolle (137.3mm, 138mm) are joined with a dovetail consisting of three full pins and two half pins.

Making dovetails by hand requires careful layout, and if two boards are to be mated together the pins of one must match exactly the tails of the other. This match can only be achieved by marking out both parts of the dovetail joint using the same template. A comparison of rubbings made of the corner joints of a select number of Hass clavichords has shown that all four corners of the case were, not surprisingly, marked out with the same template. Furthemore, the dovetails of the 1743b HH, the 1755 JH and the 1763a (and presumably all other five-octave clavichords as well) have an identical form and spacing and must, therefore, have all been marked out with the same template.

Two transverse keywell braces, jointed to the spine and the case front, play an important part in the strength and rigidity of Hass clavichords. The treble keywell brace, reduced slightly in height within the instrument to enable it to be used as a support for the left-hand edge of the soundboard, is tenoned into two mortises in the spine. The bass keywell brace, considerably reduced in height within the instrument to prevent it from obscuring the rack and to enable it to be used as a support for the keylever back touchrail, is secured to the spine with just a single mortise-and-tenon joint in the lower part of the spine. At the case front, the treble and bass keywell braces form a corner with the right-hand case front and the toolbox front respectively. In all models the upper part of this corner is secured with a dovetail joint of two full pins and one half pin plus a mitre for the case top moulding. Both braces are also tenoned into single mortises in the lower part of the case front. All the tenons at the back and at the front of the case are expanded in their mortises with a wedge.

Both the keywell braces are important not only to enhance the rigidity of the front and spine of the case but also for the correct division of the case into three unequal sections. They determine the right-hand soundboard area, the width of the keywell and the keys, and the left-hand area behind the toolbox. The bass keywell brace is positioned about 5 Zolle (nominally 119.4mm) from the left-hand case end, while the treble keywell brace is positioned from between 29 and 32¼ Zolle (nominally 692.3mm and 769.9mm respectively) from the right-hand case end depending upon the compass and model of the instrument. A bevelled recess in both keywell braces, 6 and $6^1/_3$ Zolle (nominally 143.2mm and 151.2mm) from the case front of C to $d^3$ and FF to $f^3$ models respectively, positions the nameboard at the rear of the keywell. The bass keywell brace is always positioned perpendicularly to the spine. In C to $d^3$ models the treble keywell brace is also positioned at right angles to the spine, but in FF to $f^3$ models the treble keywell brace is set diagonally, such that it is further to the right at the case front than at the spine. In all models the treble keywell brace has a hole, colloquially known as a mousehole, which consists of a rectangular-shaped cutout with a semicircle at either end.[4] Although I have been unable to find an example of this shape in contemporary eighteenth-century North-German furniture, the panelling of the altar-rail of the Leufsta Bruks kyrka, Sweden, and the pews of the Trinitatis Kirke, Copenhagen, Denmark make use of this shape.

[4] It is generally accepted, although not in fact the case, that the mousehole is critical to the sound of an instrument. The effect of the size of the mousehole on the air resonance of the cavity beneath the soundboard is discussed in chapter 5, pp.158-60.

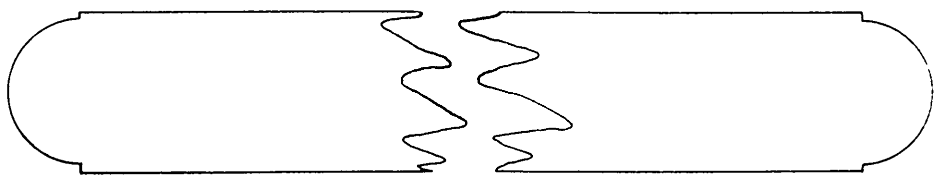


**Figure 4.6**
**The shape of the mousehole in the treble keywell brace**
Scale 1:1

The C to $d^3$ clavichords have only the baseboard, case sides, the keywell braces, and their dovetail joints to prevent the case from twisting. In order to overcome the greater string tension and increased risk of case twist in the five-octave FF to $f^3$ clavichords these larger instruments also have either a diagonal brace, a central transverse brace, or a combination of the two positioned between the treble and bass keywell braces. Both the diagonal brace and the central transverse brace are glued and dowelled to the baseboard, but they are not jointed into the case sides. Five of the six extant Hieronymus Hass FF to $f^3$ clavichords, the 1742a HH, the 1743a HH, the 1743b HH, the 1744a HH and the 1744b HH, have a diagonal brace (the most useful type of framing member to withstand the static tension of the diagonally-positioned strings) running from the rear left to the front right of the case between the two keywell braces. In addition to a diagonal brace three of these instruments, the 1742a HH, the 1743b HH and the 1744a HH also have a central transverse brace positioned at right angles to the spine and lap-jointed to the diagonal brace at the intersection between the two braces. Only one Hieronymus Hass five-octave clavichord, the 1742b HH, does not have a diagonal brace. This instrument, together with all Johann Hass FF to $f^3$ clavichords have a central transverse brace spanning the entire width of the case, which can do little to prevent the case from twisting.

There are several pine battens, known as liners, 12 to 15mm thick glued to the case walls in the right-hand portion of the case: a lower-level liner along the spine and right-hand case end helps support the 8ft wrestplank; and two upper-level soundboard liners along the spine and right-hand case front help support the soundboard. Although the height of the case (without the baseboard) varies, the top surface of the upper-level liners is always set $1\frac{1}{2}$ Zolle (nominally 35.8mm) below the top of the case. Opposite the treble and bass ends of the 8ft bridge, the upper-level liners are chamfered to enable the soundboard to vibrate more freely above the chamfered areas. There are two cutouts in both the the soundboard front liner and the treble keywell brace, which enables the scalloped ends of the 4ft hitchpin rail and the cutoff bar to be trapped between the soundboard and the front upper-level soundboard liner, and the soundboard and the treble keywell brace.

Hass often makes use of pine support blocks under important structural elements, all of which are glued to the baseboard. One such block is used beside the treble keywell brace in all models to help support the back touchrail. Hieronymus Hass FF to $f^3$ clavichords without a central transverse brace in the keywell also have a central touchrail support block. Two larger support blocks are used under the 8ft wrestplank: one is positioned at the right-hand or treble case end beneath the lap-joint between the two wrestplank sections and the other is positioned against the spine where the diagonal section of the wretsplank is let into the spine upper-level soundboard liner. In all but one five-octave FF to $f^3$ clavichord, the 1742a HH where it is not required, there is also a pine support block fitted between the 4ft wrestplank and the left-hand keywell brace. This block helps support the veneer spanning the gap between the wrestplank and the bass keywell brace.

A pine batten $^2/_3$ Zoll thick (nominally 15.9mm), known as the back touchrail, spans the distance between the left-hand case end and the treble keywell brace along the spine of the instrument. Although of a constant thickness, the rail is tapered in width from bass to treble. The left-hand end of the touchrail is set into a rectangular-shaped cutout in the upper surface of the bass keywell brace and is also attached to the spine end of the 4ft wrestplank with a corner half-lap joint. The right-hand end of the rail is supported by a small pine block butted up against the treble keywell brace. The back touchrail has two functions: the rear part provides a surface onto which the keylever guide rack is glued and the near part of the rail, which projects about 1 Zoll in front of the tapered rack, supports the tails of the keylevers. To cushion the tails of the keylevers the upper surface of the rail in front of the rack is padded. Only five instruments, the (1725) HH, the 1742a HH, the 1743b HH, the 1760b JH and the 1763a JH have old and perhaps original backrail cloths. In all five cases the backrail cloth, which is glued to the upper surface of the touchrail, consists of two layers of a red-coloured woven material stitched together. The material, which is cut to a width of about 1 Zoll, is probably wool. Since the weave cannot be seen the wool has probably been teasled.

As already shown in chapter 3, the outside case measurements (excluding the thickness of the baseboard) can, in general, only be expressed in near multiples of the Hamburg Zoll. The basic measurements and nominal Hamburg equivalents of the six standard sizes of Hass clavichord - two C to $d^3$ models and four FF to $f^3$ models - together with the (1725) HH, 1732b HH, 1748 JH and 1761a JH are given in tables 4.1 to 4.3. All of the measurements are based on either the quadrisection or the trisection of the Zoll, which would imply that the Zoll used in the Hass family's workshop was divided into twelfths. Instruments with the same compass and dimensions are grouped together in each table, and it is the mathematical mean of the instruments within each group which has been used to determine the nominal Hamburg equivalents. There are two exceptions: neither the $4\frac{1}{2}$ Zolle (nominally 107.4mm) case height of the 1740b HH, nor the $6^1/_3$ Zolle (nominally 151.2mm) case height of the 1767 JH has been included in the determination of the mean case height of their respective models, since they are significantly different from the others in their group.

**Table 4.1**
**Case dimensions of C to $d^3$ models**

EARLY SIGNED (HIERONYMUS HASS) MODEL

| | Case dimensions | | | Averages | | |
|---|---|---|---|---|---|---|
| | 1728 HH | 1740a HH | 1740b HH | actual | nominal | |
| | mm | mm | mm | mm | mm | Zolle |
| LENGTH | 1514 | 1514 | 1517 | 1515.0 | 1516.0 | 63½ |
| WIDTH | 432 | 430 | 432 | 431.3 | 429.7 | 18 |
| RIGHT-HAND FRONT | ≈685 | 685 | 689½ | 686.5 | 686.4 | $28^3/_4$ |
| HEIGHT | 120 | 118 | 109½ | 119.0 | 119.4 | 5 |

LATE (JOHANN HASS) MODEL

| | Case dimensions | | | Averages | | |
|---|---|---|---|---|---|---|
| | 1746 JH | 1756 JH | 1761b JH | actual | nominal | |
| | mm | mm | mm | mm | mm | Zolle |
| LENGTH | 1574 | 1563 | 1567 | 1568.0 | 1567.7 | $65^2/_3$ |
| WIDTH | 445 | 452 | 448 | 448.3 | 447.6 | $18^3/_4$ |
| RIGHT-HAND FRONT | 743 | 740 | 736 | 739.7 | 740.1 | 31 |
| HEIGHT | 116 | 117 | 116 | 116.3 | 115.4 | $4^5/_6$ |

**Table 4.2**
**Case dimensions of FF to $f^3$ MODELS**

EARLY (HIERONYMUS HASS) MODEL

| | Case dimensions | | | | Averages | | |
|---|---|---|---|---|---|---|---|
| | 1742a HH | 1742b HH | 1743a HH | 1743b HH | actual | nominal | |
| | mm | mm | mm | mm | mm | mm | Zolle |
| LENGTH | 1698 | 1703 | 1702 | 1700 | 1700.8 | 1701.0 | 71¼ |
| WIDTH | 524 | 520 | 521 | 518 | 520.8 | 519.2 | 21¾ |
| RIGHT-HAND FRONT | 728 | 733 | 729 | 728 | 729.5 | 728.2 | 30½ |
| HEIGHT | 138 | 140½ | 132 | 139 | 137.4 | 137.3 | 5¾ |

MIDDLE (HIERONYMUS HASS) MODEL

| | Case dimensions | | Averages | | |
|---|---|---|---|---|---|
| | 1744a HH | 1744b HH | actual | nominal | |
| | mm | mm | mm | mm | Zolle |
| LENGTH | 1714½ | 1719 | 1716.8 | 1718.9 | 72 |
| WIDTH | 520 | 520 | 520.0 | 519.3 | 21¾ |
| RIGHT-HAND FRONT | 742½ | 745 | 743.8 | 746.1 | 31¼ |
| HEIGHT | 138 | 139½ | 138.8 | 137.3 | 5¾ |

MIDDLE (JOHANN HASS) Model

| | Case dimensions | | | Averages | | |
|---|---|---|---|---|---|---|
| | 1747 JH | 1755 JH | 1760b JH | actual | nominal | |
| | mm | mm | mm | mm | mm | Zolle |
| LENGTH | 1725 | 1720 | 1719½ | 1721.5 | 1718.9 | 72 |
| WIDTH | 531 | 527 | 527½ | 528.5 | 531.2 | 22¼ |
| RIGHT-HAND FRONT | 751 | 755 | 751 | 752.3 | 752.0 | 31½ |
| HEIGHT | 138 | 139 | 140 | 139.0 | 139.3 | 5⅚ |

LATE (JOHANN HASS) MODEL

| | Case dimensions | | | | | Averages | | |
|---|---|---|---|---|---|---|---|---|
| | 1761c JH | 1762 JH | 1763a JH | 1763b JH | 1767 JH | actual | nominal | |
| | mm | mm | mm | mm | mm | mm | mm | Zolle |
| LENGTH | 1729 | 1736 | 1730 | 1738 | 1738 | 1734.2 | 1734.8 | 72⅔ |
| WIDTH | 533 | 536 | 535 | 530 | 537 | 534.2 | 533.2 | 22⅓ |
| RIGHT-HAND FRONT | 763 | 765½ | 760 | 770 | 770 | 765.7 | 764.0 | 32 |
| HEIGHT | 138 | 138 | 140 | 137½ | 151 | 138.4 | 139.3 | 5⅚ |

**Table 4.3**
**Case dimensions of unique models**

| | Length | | | Width | | | Right-hand front | | | Height | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | actual | nominal | | actual | nominal | | actual | nominal | | actual | nominal | |
| | mm | mm | Zolle | mm | mm | Zolle | mm | mm | Zolle | mm | mm | Zolle |
| C to $d^3$ | | | | | | | | | | | | |
| 1725 HH | 1516 | 1516.0 | 63½ | 423 | 423.8 | $17^{3}/_{4}$ | 682 | 680.4 | 28½ | 94 | 95.5 | 4 |
| FF to $d^3$ | | | | | | | | | | | | |
| 1732b HH | 1709 | 1707.0 | 71½ | 496 | 495.4 | $20^{3}/_{4}$ | ≈776 | 775.9 | 32½ | 139 | 139.3 | $5^{5}/_{6}$ |
| GG to $d^3$ | | | | | | | | | | | | |
| 1748 JH | 1672 | 1671.2 | 70 | 512 | 513.3 | 21½ | 772 | 771.9 | $32^{1}/_{3}$ | 135 | 135.3 | $5^{2}/_{3}$ |
| FF to $f^3$ (3 x 8ft) | | | | | | | | | | | | |
| 1761a JH | 1729½ | 1730.9 | 72½ | 523 | 525.2 | 22 | 754 | 752.0 | 31½ | 137½ | 137.3 | $5^{3}/_{4}$ |

These case dimensions clearly show that Hieronymus and Johann Hass were evolving their clavichord design over a period of about forty years. The measurements show, for example, that both Hieronymus and Johann Hass increased the length of the right-hand case front chronologically with the date of construction, and as a result the overall case length of the later instruments is greater than the ones made at the beginning of their careers. To keep the length-to-width proportion of the case constant, at 14:4 and 13:4 for standard C to $d^3$ and FF to $f^3$ models respectively (see chapter 3, pp.57-8), Hass also increased the width of the case.

The significance of the extra space created by lengthening and widening the case can be shown by comparing the C to $d^3$ clavichords of Hieronymus with those of his son Johann Hass. By increasing the length of the right-hand case front by some 2¼ Zolle (see table 4.1) Johann Hass could increase the length of the central straight section of the 8ft bridge and still keep the ends of the bridge away from the relatively stiff soundboard areas near the case sides. In turn, this increase in the length of the bridge meant that Hass was then able to provide his C to $d^3$ clavichords with one extra pair of bridge pins and so start fretting at the note f, two notes later than the design of Hieronymus Hass. Johann Hass was also able to increase the length of the bass 8ft scalings by about 30mm. This evolution in the C to $d^3$ design of Hass clavichords is shown in table 4.4, which gives the length of the right-hand case front for the 1740b HH and the 1761b JH, together with the string scalings for the notes C and $d^3$, the distance from the right-hand case end of the nearest pin of the pair of 8ft bridge pins for the same two notes, and the distance of the same two pins from the spine of the case.

**Table 4.4**
**The development of the C to $d^3$ model (in mm)**

| | LENGTH OF RIGHT-HAND FRONT | STRING SCALING | | BRIDGE PINS FROM RIGHT-HAND END | | BRIDGE PINS FROM SPINE | |
|---|---|---|---|---|---|---|---|
| | | C | $d^3$ | C | $d^3$ | C | $d^3$ |
| 1740b HH | 689½ | 1301 | 121 | 115 | 567 | 307 | 34 |
| 1761b JH | 736 | 1328 | 122 | 132 | 611 | 319 | 36 |

Hieronymus and Johann Hass were almost continually increasing the soundboard area of their FF to $f^3$ models. As with the C to $d^3$ model the extra space created in this way enabled both makers to increase the length of the bass strings, and at the same time keep the ends of the 8ft bridge away from the case sides. Since both father and son seem always to have been aiming for the same nominal treble scalings, in order for them to increase the length of the bass scalings they needed both to increase the length of the 8ft bridge and to change its orientation relative to the right-hand case end. I have found that although the bass end of the 8ft bridge is usually very close to 6 Zolle (nominally 143.2mm) from the inside of the right-hand end of the case,[5] the treble end of the bridge is positioned further from the right-hand end in later models than in earlier ones: the treble end of the 8ft bridge of the 1742a HH, for example, is positioned about 27 Zolle (nominally 644.6mm) from the

[5] In the case of the 1767 JH, however, the bass end of the 8ft bridge is positioned about $5^3/_4$ Zolle (nominally 137.3mm) from the inside right-hand end of the case.

side of the case, whereas that of the 1767 JH is positioned about 29 Zolle (nominally 692.3mm) from the side of the case. Table 4.5 shows the evolutionary nature of the length of the right-hand case front, together with the bearing this has on the length of the bass scalings and the orientation of the bridge. I believe that Hass found that when he changed the orientation of the 8ft bridge this then necessitated changes in the pattern of the rack-slot spacings and in the curvature of the treble end of the 8ft bridge in order to keep the treble string scalings constant. These changes are discussed in the sections on the rack and the bridge.

**Table 4.5**
**The development of the FF to $f^3$ model (in mm)**

| | LENGTH OF RIGHT-HAND FRONT | STRING SCALING | | BRIDGE PINS FROM RIGHT-HAND END | | BRIDGE PINS FROM SPINE | |
|---|---|---|---|---|---|---|---|
| | | FF | $f^3$ | FF | $f^3$ | FF | $f^3$ |
| 1742a HH | 728 | 1445 | 105 | 144 | 649 | 397 | 35½ |
| 1744a HH | 742½ | 1458 | 104 | 146 | 658 | 403 | 34 |
| 1763a JH | 760 | 1473 | 103 | 149 | 678 | 408 | 35 |
| 1767 JH | 770 | 1489 | 103 | 137 | 693 | 421 | 39½ |

Although the case length-to-width is a constant proportion, the case height of five-octave FF to $f^3$ models tends to stay the same, nominally at $5^3/_4$ Zolle, and is therefore not in proportion to the length and width of the case sides. Only the case of the 1767 JH, with a height of $6^1/_3$ Zolle, is exceptional. In contrast to the FF to $f^3$ models, the C to $d^3$ clavichords of Hieronymus Hass have three different case heights: nominally 4, 4½ and 5 Hamburg Zolle.

## THE 8FT WRESTPLANK AND 8FT TUNING PINS

The wrestplank for the 8ft tuning pins is located in the right-hand end of the case and consists of two blocks of beech (*Fagus sylvatica*) lap-jointed together. One block, which is glued onto the lower-level liner along the inside of the right-hand case end, runs the entire width of the clavichord. The other block, which is positioned diagonally between the right-hand case end and the spine, is lap-jointed to the first block at 60° and is glued onto the lower-level liner attached to the inside of the spine (see plate 4.1). There is a chamfer on the left-hand edge of the transverse section of the 8ft wrestplank near to the front of the case. This chamfer increases the amount of free-vibrating soundboard area at the bass end of the 8ft bridge.

The tuning pins for the 8ft strings are made from pieces of iron rod. One end of the tuning pin is tapered to about one-third of its diameter, whilst the other end is hammered to a thickness of about 2mm and the top filed flat to take the tuning hammer. In all models the 8ft tuning pins are about 2 Zolle (nominally 49½mm) long in total, and usually extend between 1¼ (nominally 29.8mm) and 1½ Zolle (nominally 35.8mm) above the top surface of the soundboard. The thickness of the iron rod used for the tuning pins varies from 3.5 to 4.2mm thick, with three different sizes of rod used for the five-octave FF to $f^3$ instruments and two sizes of rod for the C to $d^3$ instruments. The thinnest rod is used for the highest notes since it is easier to tune a short string with a tuning pin of small diameter. As well as using rod of different thicknesses on instruments made in different years (see table 4.6), the note of transition from one gauge of rod to the next also varies. These variations are, however, not consistent in all of the instruments in the early, middle and late models, and consequently may have come about solely as a result of the availability of certain gauges.

**Table 4.6**
**Sizes of 8ft tuning pins**

| FF to $f^3$ | | | | C to $d^3$ | | | |
|---|---|---|---|---|---|---|---|
| 1743b HH | | 1763b JH | | 1740b HH | | 1761b JH | |
| NOTES | DIAMETER | NOTES | DIAMETER | NOTES | DIAMETER | NOTES | DIAMETER |
| $g^1$-$f^3$ | 3.5 | $b^{b1}$-$f^3$ | 3.5 | c-$d^3$ | 3.5 | a-$d^3$ | 3.5 |
| e-$f^{\#1}$ | 3.8 | C-$a^1$ | 3.9 | C-B | 4.0 | C-$g^{\#}$ | 4.0 |
| FF-$e^b$ | 4.0 | FF-BB | 4.2 | | | | |

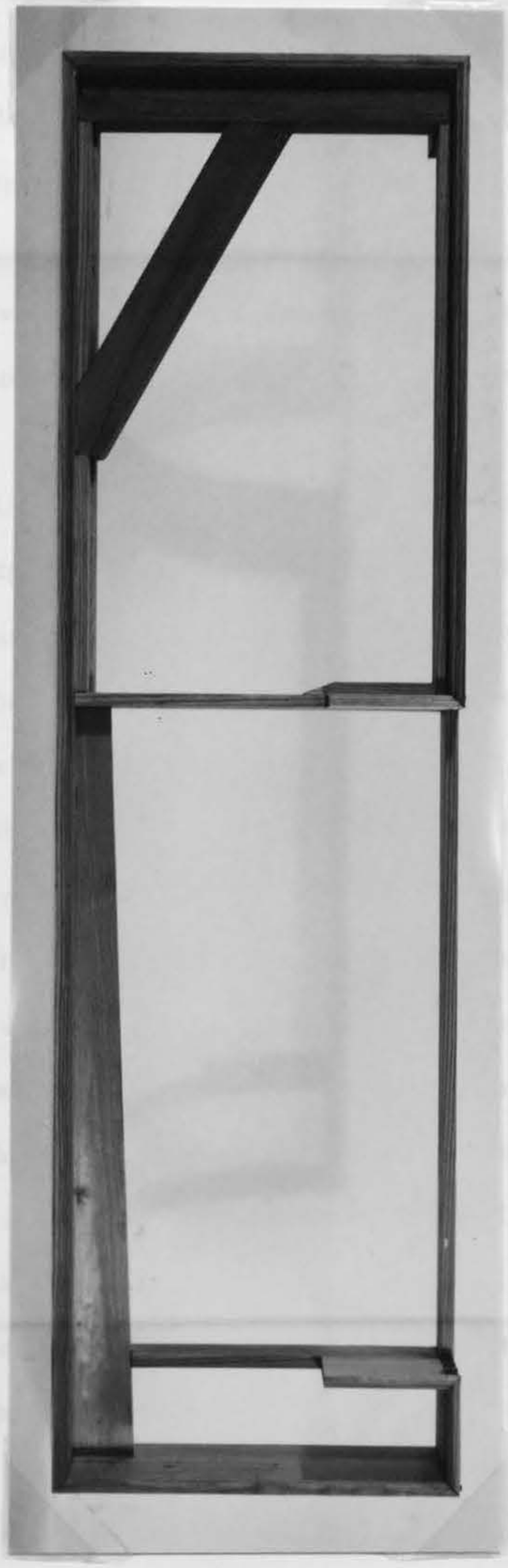


Plate 4.1
**Internal framing and 8ft wrestplank of a C to $d^3$ clavichord**
(modern copy by the author)

**THE 4FT WRESTPLANK AND 4FT TUNING PINS**

The wrestplank for both the 4ft tuning pins and the bass 8ft hitchpins usually appears to be made from a solid block of walnut. However, in all C to $d^3$ clavichords and the FF to $f^3$ 1742b HH, where it is possible to view the underside of the wrestplank, it is actually made from a block of beech (*Fagus sylvatica*), which has been veneered on its upper surface and right-hand side in walnut (*Juglans regia*). The veneering is so well executed that it is almost impossible to determine the construction of the 4ft wrestplank without viewing the underside of the instrument.

Unfortunately, with the exception of the 1742b HH, the underside of the 4ft wrestplank of the FF to $f^3$ clavichords is obscured by a piece of veneer, known as a capping piece, which bridges the space between the side of the 4ft wrestplank and the bass keywell brace. It is probable, however, that the 4ft wrestplank of FF to $f^3$ models is made in the same way as that of the C to $d^3$ instruments, since it has been possible to verify beech as the main wood type in three cases, the 1742b HH, the 1761c JH and the 1763a JH. It was possible to view the underside of the 4ft wrestplank of the 1742b HH (and therefore determine that it is made from beech and veneered in walnut) because there is no capping piece between the bass keywell brace and the 4ft wrestplank. Christopher Clarke has found that the 4ft wrestplank of the 1761c JH is constructed in this same manner, since during the restoration of this instrument the baseboard was removed. In the case of the 1763a JH the wrestplank is unusual in that it is veneered in Kingwood, but here too it has been possible to determine that beech is used for the core of the wrestplank, since a small portion of the moulding along the top right-hand corner of the wrestplank is loose.

There is only one clavichord where the core of the 4ft wrestplank is known to be constructed from a wood other than beech: in the case of the FF to $d^3$ 1732b HH the wrestplank is made from lime (possibly *Tilia vulgaris*) and veneered in walnut.

The 4ft wrestplank of all models is $1^3/_4$ Zolle (nominally 41.8mm, actual mean 42mm) wide, and is positioned 1 Zolle (nominally 23.87mm) below the top edge of the case. In the C to $d^3$ models, and in all other instruments in which the underside of the 4ft wrestplank is clearly visible, the wrestplank is of a rectangular cross-section with the lower right-hand corner planed off. It is not clear why the wrest-plank is chamfered in this manner, but it may have been done for aesthetic reasons, at least in the case of C to $d^3$ models. As well as being glued to the side of the case, the wrestplank is secured to the bass end of the rack with a corner half-lap joint at its far end (see figure 4.7) and is let into the rear side of the toolbox backing piece at its front end (see figure 4.8). Although it is not possible to be certain of the exact construction of the 4ft wrestplank of the FF to $f^3$ instruments photographs of the underside of the 1761c JH taken during restoration suggest that the wrestplanks of five-octave models also have the lower right-hand corner planed off.

The 4ft tuning pins, positioned in two straight rows along the top of the 4ft wrestplank, are constructed from pieces of iron rod in exactly the same way as the 8ft tuning pins. The thickness of the iron rod varies between 3.0mm and 3.4mm in different instruments, but only one gauge of rod is used in a single instrument. Each of the 4ft tuning pins is about $1^2/_3$ Zolle long (nominally 39.8mm) in total, and is set into the wrestplank such that about $^7/_8$ Zoll (nominally 20.9mm) of the pin protrudes above its top surface.

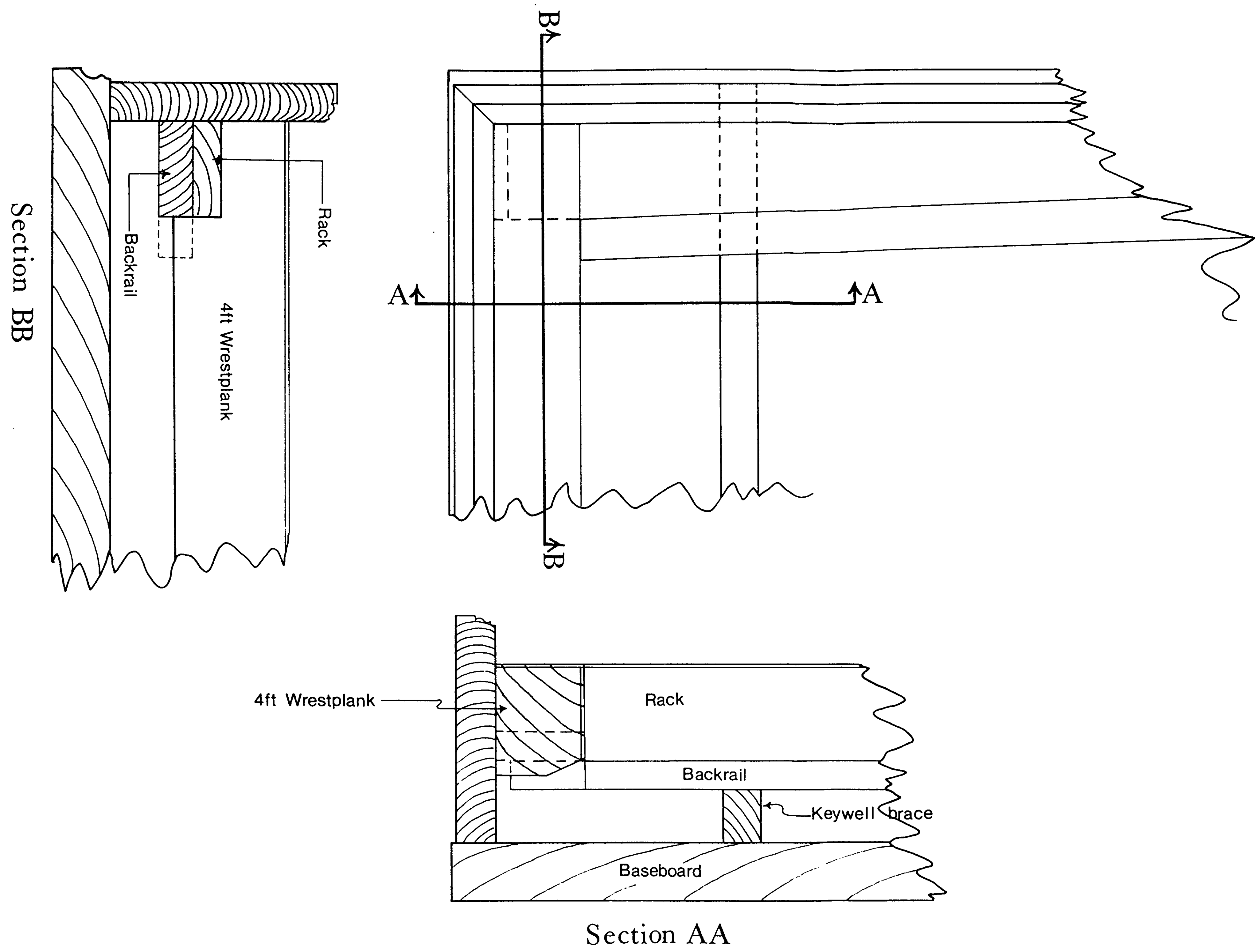



**Figure 4.7**
**Rear left-hand corner of the (1725) HH**
Scale 1:2

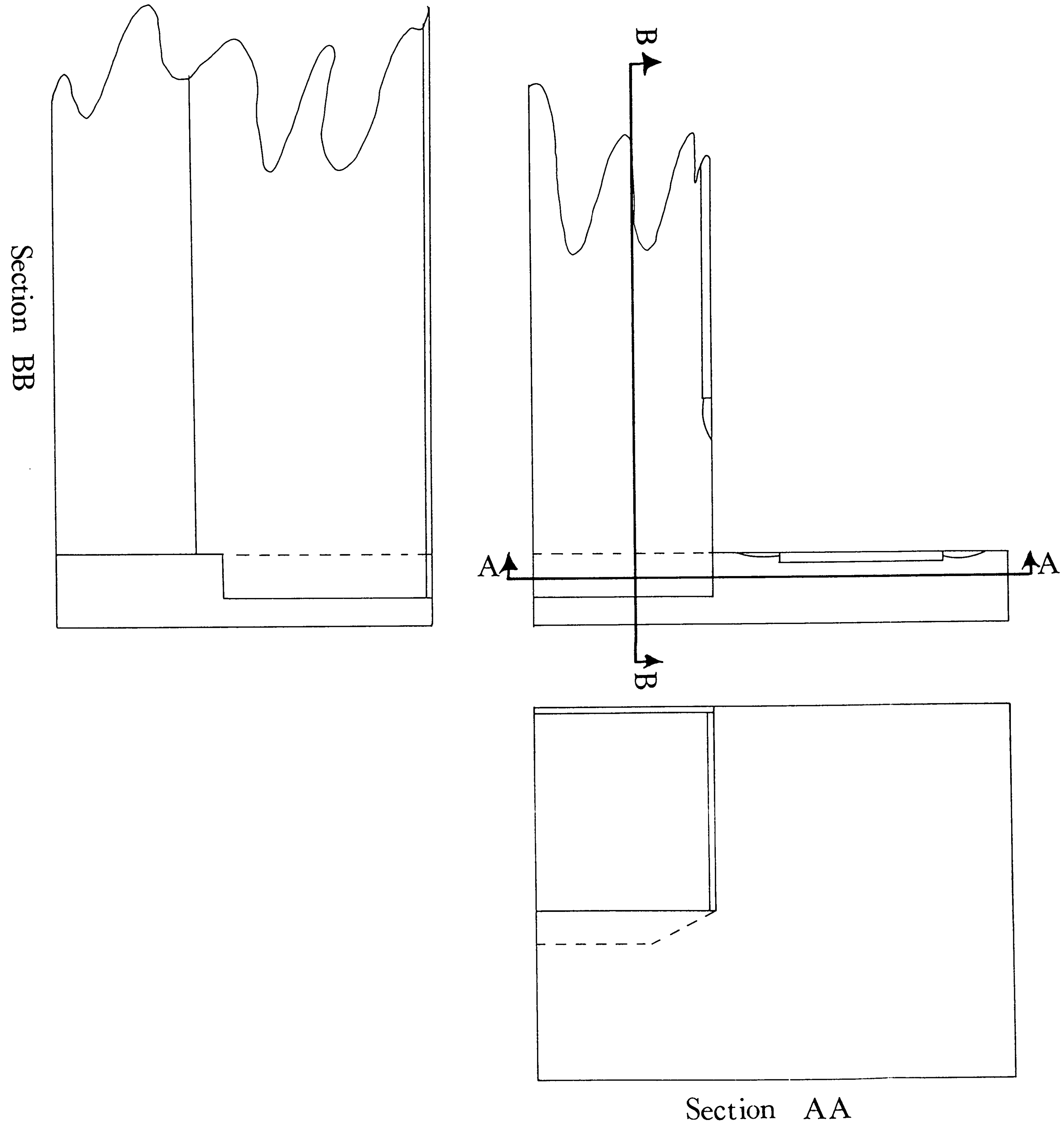



**Figure 4.8**
**Near end of the 4ft wrestplank of the (1725) HH**
Scale 1:1

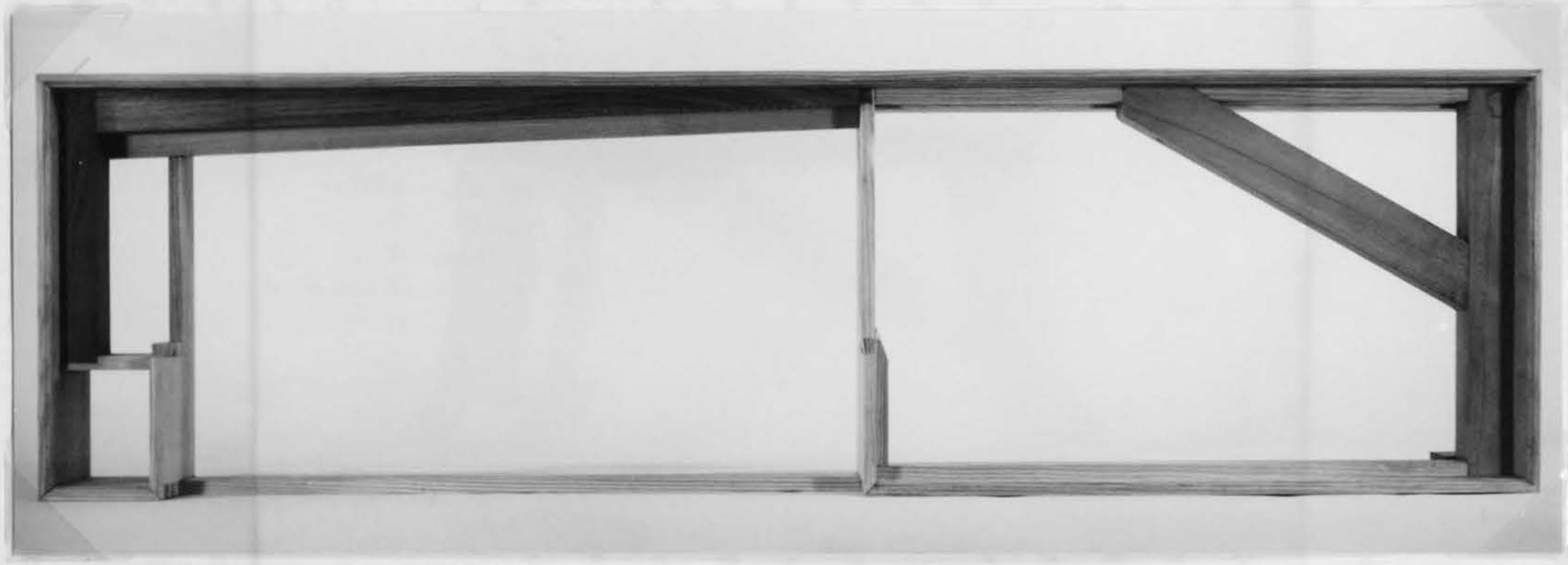


Plate 4.2
**Internal framing, 8ft & 4ft wrestplanks and rack of a C to $d^3$ clavichord**
(modern copy by the author)

**THE RACK**

The rack has a series of vertical slots cut into its front face in which the key-lever guide tongues ride; and these slots open out into the interior of the rack. In all cases the rack is glued to the inside of the spine and to the top of the back touchrail between the 4ft wrestplank and the treble keywell brace (see plate 4.2). Although the wood has not been microscopically examined the presence of chocolate-brown flecks on the front face of most racks indicates that beech (*Fagus sylvatica*) is the most likely timber.[6] It is, however, not possible to know if the rack of the 1763a JH is made from beech since both the front face and the upper surface of this rack are veneered in Kingwood. In all instances where beech has been used the front face of the rack, which runs parallel to the front edge of the back touchrail, is stained the colour of walnut. The top surface of the rack is usually veneered in walnut $1\frac{1}{2}$-2mm thick, which covers over the tops of the rack slots. Olive wood veneer covers the top surface of the rack of the 1755 JH. Although the treble end of the rack is always $^2/_3$ Zoll (nominally 15.9mm) thick, the thickness of the bass end is variable: the rack width at the bottom slot of the C to $d^3$ models is usually $1^2/_3$ Zolle (nominally 39.8mm), whilst the rack width of FF to $f^3$ models at the bottom slot varies from $2\frac{1}{2}$ Zolle (nomimally 59.7mm) on the 1742a HH to 3 Zolle (71.6mm) on the 1767 JH.

The actual spacing of the rack slots is an element in the design and correct functioning of the clavichord. It is the spacing of the rack slots together with the shape and placement of the bridge and the bridge-pin spacing which determines the accuracy of the string scalings. An analysis of rubbings made of the rack-slot spacings has revealed that some clavichords have identical rack-slot spacing patterns. Both the 1755 JH and the 1760b JH, for example, have the same rack-slot spacing

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[6] The one exception to this is the rack of the 1732b HH which, like that of Hass harpsichords, appears to be made from unstained lime (probably *Tilia vulgaris*).

pattern, and the 1761c JH, the 1762 JH, the 1763a JH and the 1763b JH all have the same rack-slot spacing pattern which is different from that of the 1755 JH and the 1760b JH. This implies that Hass used a rack ruler or calibrated stick to mark the position of the vertical slots onto the front of the rack. In total, I have determined that the Hass family must have used at least fourteen different rack rulers, including five different patterns among the C to $d^3$ clavichords and six different designs among the standard FF to $f^3$ clavichords. The rack-slot spacing patterns of most of the surviving Hass clavichords are given in table 4.7 below. Four instruments are absent from this table: the 1754 HH and the 1761d JH are not included because they have only recently come to light; permission was not given to make a rack rubbing of the 1743a HH; and it was not possible for me to make a rack rubbing of the 1744b HH because the original rack slots are obscured by later vertically-positioned slips of wood between which the tails of the keylevers now ride.

**Table 4.7**
**Instruments with the same rack-slot spacing patterns**

| Instrument | Compass | Pattern |
|---|---|---|
| (1725)HH | C to $d^3$ | a |
| 1728 HH, 1740b HH | C to $d^3$ | b |
| 1740a HH | C to $d^3$ | c |
| 1732b HH | FF to $d^3$ | d |
| 1742a HH, 1742b HH, 1743b HH | FF to $f^3$ | e |
| 1744a HH | FF to $f^3$ | f |
| | | |
| 1746 JH | C to $d^3$ | g |
| 1756 JH, 1761b JH | C to $d^3$ | h |
| 1748 JH | GG to $d^3$ | i |
| 1747 JH | FF to $f^3$ | j |
| 1755 JH, 1760b JH | FF to $f^3$ | k |
| 1761a JH (3 x 8ft) | FF to $f^3$ | l |
| 1761c JH, 1762 JH, 1763a JH, 1763b JH | FF to $f^3$ | m |
| 1767 JH | FF to $f^3$ | n |

Some of the differences between the rack-slot spacing patterns are very subtle. The patterns b and c are, for example, virtually the same for the bottom sixteen notes C to $e^b$, but then the spacings start to get out of step. The spacing between $f^1$ and $f^{\#1}$ on pattern c is wider than that for pattern b, for instance, but smaller between the slots for $b^{b1}$ and $b^1$. Neveretheless, the spacing between the slots for the notes $c^1$ and $c^2$ is the same and equivalent to $7^1/_3$ Zolle (nominally 175.08mm, actually 175½mm). In the case of the 1740b and the 1740a HH, which use the rack patterns b and c respectively, these differences in the rack-slot spacing are not enough to make the string scalings of the two instruments drastically different. In this instance, since the 8ft bridges of the 1740a and 1740b HH have precisely the same shape and are positioned exactly the same distance from the inside right-hand case end, the string scalings (as shown in table 4.8) are in fact very similar.

**Table 4.8**
**A comparison of the string scalings of three C to $d^3$ clavichords with different rack types**

| 1740a HH (rack type c) | | | | 1740b HH (rack type b) | | | | 1761b JH (rack type h) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8ft | | 4ft | | 8ft | | 4ft | | 8ft | | |
| $d^3$ | 126 | | | $d^3$ | 121 | | | $d^3$ | 122 | | |
| $c^3$ | 143 | | | $c^3$ | 142 | | | $c^3$ | 143½ | | |
| $f^2$ | 215 | | | $f^2$ | 220 | | | $f^2$ | 218 | | |
| $c^2$ | 286 | | | $c^2$ | 287½ | | | $c^2$ | 285 | | |
| $f^1$ | 430 | | | $f^1$ | 434 | | | $f^1$ | 437½ | | |
| $c^1$ | 570 | | | $c^1$ | 574 | | | $c^1$ | 567 | | |
| f | 815 | d | 569 | f | 823 | d | 577 | f | 829 | d | 582 |
| c | 1003 | c | 619 | c | 1012½ | c | 630 | c | 1017 | c | 631½ |
| F | 1195 | F | 805 | F | 1197 | F | 802½ | F | 1221 | F | 820 |
| C | 1302 | C | 943 | C | 1301 | C | 936 | C | 1328 | C | 957 |

Although the reason for Hieronymus Hass using two different rack marking-out sticks in 1740 is not completely clear, the thinking behind variations in rack-slot spacing patterns of instruments by Hass father and son can be more easily determined, since when either member of the Hass family changes his design, he usually changes not only the rack-slot spacing pattern but also the 8ft bridge shape. This way of working can be illustrated by a comparison of the 1740b HH and the 1761b JH, the string scalings of which are given in table 4.7. There are elements in the rack-slot spacing pattern, such as the rack-slot span (the distance from the top to the bottom rack slot), which are the same in these two instruments. The rack-slot spacing pattern in the bass and in the treble, and the diatonic semitone rack-slot spacing in the middle part of the compass are also the same. However, since the fretting of the 1761b JH starts at f-f#, two notes later than on the 1740b HH, the relatively wide rack-slot spacing between notes a chromatic semitone apart starts two notes later. The spacing between these chromatic semitone slots is also greater on the 1761b JH than on the 1740b HH to compensate for the difference in the number of fretted string pairs. A comparison of the 8ft bridge shape of these two instruments has revealed that both makers used the same gently curved bass end to the bridge between the notes C and c, and the same hooked treble end from $f^1$ to $d^3$. Since the fretting of the 1761b JH starts at f, however, two notes higher than the 1740b HH, the central straight section of the bridge between c and $f^1$ of the 1761b JH is 35mm longer than that of the 1740b HH. This is to accommodate the one extra pair of bridge pins required for the additional unfretted pair of strings.

As well as guiding the keylevers, the rear part of the block that makes up the rack also serves as a hitchpin rail for the tenor, alto and treble 8ft hitchpins for the notes from f upwards. Only the arrangement of the hitchpins of the GG to $d^3$ 1748 JH differs from this, with g as the first note on top of the rack. In all models, the hitchpins (which are angled over towards the left-hand end of the case) are made from small pieces of brass wire of 1.8mm diameter. Although it is not known if the holes for the hitchpins are angled towards the left-hand end of the case as well, it is likely that the hitchpins were angled after being positioned in vertically-drilled holes and the tops then filed flat. The hitchpins protrude above the top surface of the rack between 3.3mm and 4.8mm on different instruments. The treble, alto and tenor 8ft hitchpins of all C to $d^3$ instruments, the FF to $d^3$ 1732b HH and the trichord strung 1761a JH are positioned in a single straight line which is parallel to the front edge of the rack. In contrast, the hitchpins of all standard FF to $f^3$ instruments (as well as the GG to $d^3$ 1748 JH) are staggered in two rows along the top of the rack.

**THE BALANCE RAIL**

The balance rail is glued to the baseboard between the two keywell braces. It is rectangular in cross section with the front and back top edges chamfered to prevent the keylevers from fouling the rail. In all Hass C to $d^3$ clavichords the balance rail is about 2¼ Zolle (nominally 53.7mm) high by 2 Zolle (nominally 47.7mm) wide, and is set parallel to the front edge of the case. In contrast, the balance rail of five-octave FF to $f^3$ clavichords is about 3 Zolle (nominally 71.6mm) high by 2 Zolle (nominally 47.7mm) wide, and is set obliquely to the case front such that the treble end is further from the player than the bass end. Although the balance rail of Hieronymus Hass C to $d^3$ clavichords consists of a solid block of beech (*Fagus Sylvatica*), most balance rails are made from two blocks of wood glued together. The upper portion of bi-partite balance rails is always of beech, but the lower portion can be either lime or Scots pine. Bi-partite rails of Hieronymus Hass and most early Johann Hass clavichords are of beech on lime, whereas the later instruments of Johann Hass are always of beech on pine.

In all models, the balance pins on which the keylevers pivot are made from iron rod 2.6mm thick. The pins project about $^7/_8$ Zoll (nominally 20.9mm) above the top surface of the balance rail and the tops of the pins are slightly chamfered with a file to prevent the keylevers from sticking. The pins are positioned in two straight rows $^2/_3$ Zoll (nominally 15.9mm, actually 16½mm ) apart along the top of the balance rail, the near row for the natural keylevers and the far row for the accidental keylevers. There is a balance cord of about 1.75mm diameter glued to the top of the balance rail in front of both rows of balance pins, which acts as the fulcrum for the keylevers. The right-hand end of either cord is pegged to the balance rail, while the left-hand end of either cord is pegged to the balance rail or to the upper surface of the bass keywell brace. In order to prevent the natural and accidental keylevers from fouling with each other's balance cords, there is a wedge-shaped cutout on the underside of the keylevers. This cutout is behind the balance point of the natural keylevers and in front of the balance point of the accidental keylevers. In several instances, such as the (1725) HH and the 1755 JH, the existence of the cutout on the underside of the keylevers and the balance rail pegs is the only surviving evidence that these clavichords were originally provided with balance cords.

Three Hass clavichords, the (1725) HH, the 1747 JH and the 1760b JH have the remains of old, possibly original, balance cloths positioned along the top of the balance rail. The cloths of the 1747 JH and the 1760b JH are positioned over the balance cords, but in the case of the (1725) where there are no balance cords the cloths are positioned directly onto the balance rail. In all three clavichords there is one strip of cloth for the row of natural balance pins and one strip for the row of accidental balance pins, secured in place by the pins themselves which project through the cloth. The cloth of both the (1725) HH and the 1760b JH is woven wool 1.3 to 1.4mm thick, which has been dyed black. Unfortunately, the brown-coloured balance cloths on the 1747 JH have disintegrated to such an extent that they cannot be measured. Only two other clavichords are known to have balance cloths: the clavichord built in 1756 in Hamburg by Johann Gerlach and the clavichord built by Otto Juachim Tiefenbruun in Copenhagen in 1807.[7] The balance

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[7] This clavichord by Tiefenbruun is preserved at the Ringve Museum, Trondheim, inventory number RMT 82/4.

cloths of the clavichord made in 1756 by Gerlach consist of a blue-grey woollen ribbon. If the presence of balance cloths is an original feature of Hass clavichords, it is uncertain what function the cloths served other than slightly raising the fronts of the keys.

**THE KEYBOARD**

The keylevers of Hass clavichords are made from a panel-jointed plank of lime (*Tilia vulgaris*) 14 to 15mm thick, the grain of which runs parallel to the ends of the case. Once the keyplank had been made up the near edge was planed parallel to the case front and the far edge planed parallel to the front of the tapered rack. A number of transverse lines were then scribed onto the upper surface of the keyplank, which are still visible: a diagonal line to keep the order of the keys correct once they had been cut apart; a pair of scribed lines to mark the length of the carving on the upper surface of the keylevers; and a pair of scribed lines $^2/_3$ Zoll (nominally 15.9mm) apart to mark the balance line for the naturals and the accidentals. In C to $d^3$ models the balance lines are scribed parallel to the front of the case, but in FF to $f^3$ models the lines are scribed obliquely to the case front such that they are further from the player at the treble end than at the bass end. The position of these balance lines is important because they determine not only the mechanical advantage of each keylever and thus the feel of the instrument, but also because they determine the tangent velocity, which is one of the elements determining the volume of tone produced by the clavichord (see the section on keylever design in chapter 5, pp.154-5).

The tails of the keylevers were probably marked out by temporarily attaching the keyplank, possibly with nails, to the balance rail. A blunt tool was then positioned in each rack slot in turn and lightly hammered onto the upper surface of the keyplank. The slight indentation caused by this process is still clearly visible on the tail ends of the keylevers, and was used by Hass to transfer the rack-slot spacings to the rear edge of the keyplank so that the position of the keylever guide tongues matches the spacings of the rack slots exactly. The holes left by the nails at the ends of the balance rail could then have been used by Hass to attach the ends of the balance cords to the rail with a peg, but this is not certain. Each indentation at the tail end of the keyplank was used by Hass to scribe a vertical line on the rear edge of the keyplank, which, together with two horizontal lines scribed 3½mm apart, enabled each whale-bone guide tongue to be positioned precisely in the centre of the tail end of each keylever.

The fronts of the naturals appears to have been marked out by dividing the entire keyplank width by the required number of naturals. The width of the keyboard at the fronts of the naturals is itself the result of fitting the keyplank into the width of the keywell, with a minimal space at either end for the free movement of the top and bottom keys. In standard models, the number of Zolle between the two keywell braces is always ½ Zoll less than the number of naturals: the thirty-six naturals of FF to $f^3$ models occupy a keywell space of 35½ Zolle (nominally 847.5mm), for example, and the thirty naturals of C to $d^3$ models occupy a keywell space of 29½ Zolle (nominally 704.3mm). In theory, this means that the three-octave span (which most writers refer to as the *Stichmass*) should vary according to model. Assuming a space of 2mm at either end of the keyboard, the theoretical three-octave span of FF to $f^3$ clavichords is 492.04mm, wherereas that of C to $d^3$ clavichords is 490.21mm. In practice, however, the three-octave span of either model does not fall so clearly into either of these two categories, because the nominal span between the two keywell braces is reduced on some clavichords by the existence of olive wood veneer 1.1mm thick on the inside faces of the keywell ends. The mean three-octave span of the FF to $f^3$ 1742a HH, for example, which does have the olive wood veneer in the keywell is 490mm, whereas the mean three-octave span of the FF to $f^3$ 1742b HH which does not is 492mm. Consequently, for all models the three-octave span varies from between 488½ and 492mm.

Since the natural touchplates extend right to the edges of the keylevers and do not overhang the sides, and saw marks are sometimes visible along the edge of the natural tails, the touchplates were probably glued in place before the keys were cut apart. Natural touchplates usually consist of two pieces of ivory, one for the natural heads and one for the natural tails which run between the accidental blocks. There are four lines across the natural heads just in front of the accidental blocks: one is coincident with the joint between the two pieces of ivory and the other three are scribed. All four lines are coloured with a red pigment, possibly vermilion (red lead oxide). X-ray fluorescence of the keys of the clavichord made in 1756 in Hamburg by Johann Gerlach showed that there was a strong concentration of mercury in this red pigment, proving that it must be vermilion which is mercuric oxide.[8] The natural plates of four clavichords, the 1728 HH, the 1740b HH, the 1763a JH and the 1767 JH are of tortoise-shell. Silver foil was usually placed beneath the tortoise-shell to reflect the light and exploit the natural colour variations of the shell, but the remains of a whiting at the tail ends of the natural plates may indicate that Hass used gesso or paint to create the same effect. The standard method of tortoise-shell preparation is to immerse the material in hot water until it becomes soft and malleable and then compress it into blocks. When dry these blocks can be sliced into plates ready for gluing into place.[9] The scribed lines of the tortoise-shell naturals are filled with a whiting.

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8 G. O'Brien, "Case Study: An unfretted Clavichord by I.C. Gerlach, Hamburg, 1756, or what can be learned by not restoring," paper given at Antwerp, (Edinburgh, 1991), p.7.

9 Personal correspondence with the Cambridge bowmaker Richard Wilson.

Once the keylevers had been cut apart the top and the front edge of the natural plates were rounded. The sides of the naturals were also rounded to the first of the four decorative lines, except for the right-hand edge of the top key and the left-hand edge of the bottom key which were left straight. The front of each natural keylever was then decorated with an arcade, usually consisting of a small rectangular block of ebony or ivory into which a semi-circular moulding has been cut. Two other types of arcade were occasionally used: both the 1732b HH and the 1740a HH have the remains of paper arcades, which consist of a central fleur-de-lis or heraldic lily with three petals cut from white paper and glued onto a red-coloured paper backing; and the (1725) HH has unique leather arcades with a central embossed fleur-de-lis. In all cases, however, the natural plates overhang the front of the arcade by 1 to 2mm. Since the arcades sometimes slightly overlap the sides of the keylever they must have been glued on individually after the keys were cut apart.

After separating the keys, the sides of each of the keylevers were trimmed and the upper surface carved. The marks left by the saw cuts were removed from the sides of the keylevers with a spokeshave and/or a chisel, and a wedge-shaped cutout was made on the underside of each lever with a chisel, in front of each natural key's balance point and behind each accidental key's balance point. Along the length of the keylevers between the balance point and the tangent the upper surface was decoratively carved. The natural keylevers were roof-carved to a central peak, whilst the accidental keylevers of all Hieronymus Hass instruments and early Johann Hass instruments were carved in a meander-like pattern (see figure 4.9). All the keys of late Johann Hass instruments (from the 1755 JH onwards) were, like the natural keylevers, roof-carved. A comparison of rubbings made of the top-surface of the meander pattern has shown that Hass used a template to mark out this design. To help in the waveform carving, the centre and depth of the meander was marked on both sides of the accidental keylevers with a single horizontal scribed line.

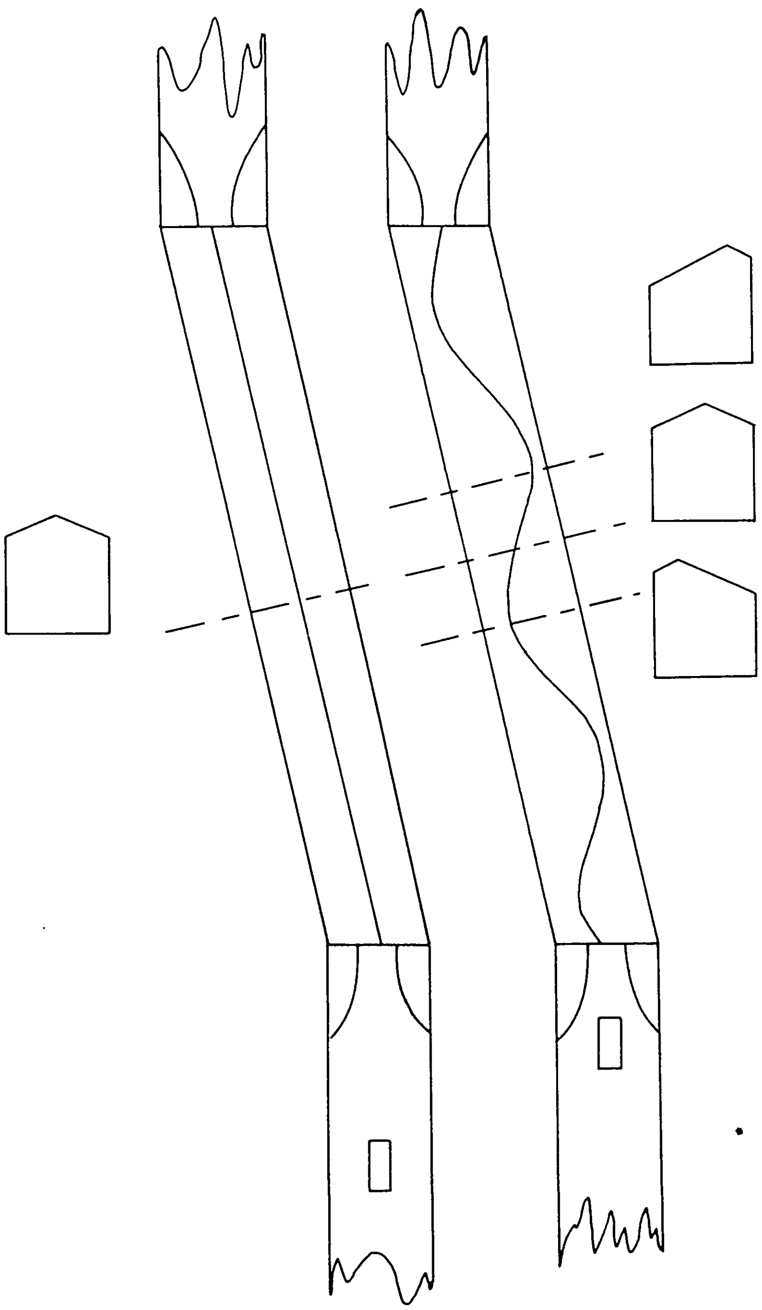
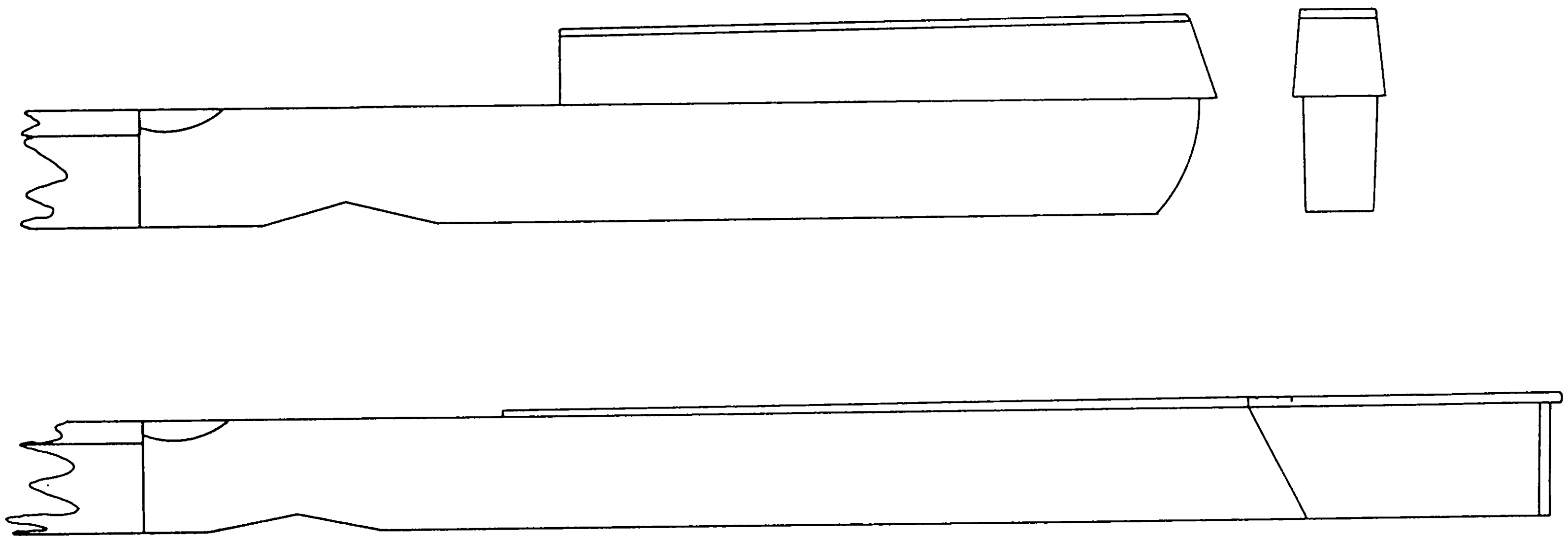


**Figure 4.9**
**The two types of keylever carving**
(Scale 1:1)

The accidental blocks are usually composed of a block of ebonised lime which is veneered on the top surface with either ebony, tortoise-shell or mother-of-pearl. Two Hass clavichords have unusual accidental blocks: the (1725) HH accidental blocks are made from beech rather than lime, whilst those of the 1740b HH consist of an ebonised block of horn in which is set a piece of engraved mother-of-pearl.[10] The accidental veneer of some instruments is fashioned from many small diamond-shaped pieces of two contrasting materials (such as ebony and ivory on the 1743a HH or mother-of-pearl and tortoise-shell on the 1767 JH) arranged in a chevron pattern. The accidental veneer of the 1755 JH, consisting of an arabesque pattern in ivory and tortoise-shell, was made using marquetry techniques. Accidental blocks of all models are about 3½ Zolle (nominally 83.6mm) long and taper slightly in height from front to back, and the fronts and sides of the accidental blocks are slightly bevelled. The dimensions of the accidental blocks can vary by about 1mm even on the same instrument, which indicates that the sides of the accidentals were probably planed by eye and not with the aid of a jig. Once the blocks were glued in place the sides and front of each accidental, together with the keylever beneath the accidental, were stained black with ink. The accidental blocks were then varnished.

[10] Mother-of-pearl is so delicate that even light pressure will crack it, and it must therefore have been reinforced before it was sawn or filed to make the accidental veneer. The standard method of reinforcement is to back the mother-of-pearl with a stiff veneer and a paper interleaf.



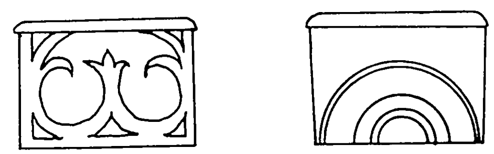


**Figure 4.10**
**Accidental blocks, natural touchplates and arcades**
(Scale 1:1)

Beneath the keylevers of the 1767 JH there is a board, similar to that found in some sixteenth-century clavichords, which is glued to the upper surface of the two keywell braces and the central transverse brace. The board is constructed, like the soundboard, from several planks of close-grained white coniferous wood (probably spruce) edge-jointed together, with the grain running parallel to the spine of the case. The function of this board is unknown, but the board appears to be too thin to have any structural function and is unable to perform any acoustical function since there is no contact between the board and the strings.[11]

**THE TANGENTS**

It is likely that the tangents were positioned in the tail end of the keylevers (and in a line with the guide tongues) as the instrument was being strung, since it is much easier to remove the keylevers without all the strings in place, and any slight mispositioning of the hitchpins or the bridge pins can be compensated for by moving the tangent nearer to or further from the player. All the tangents are cut from 0.6mm thick brass sheet, and flare outwards towards their head. As the string spacing between successive pairs of bridge pins becomes progressively narrower towards the treble, so the head width of the tangents also becomes narrower towards the treble. The head width of each tangent of a select number of Hass clavichords was measured with a pair of vernier calipers. These measurements were then plotted cumulatively on graph paper so that any changes in the head width could be seen as a change in the slope of the line joining the plotted points. The arithmetical mean of each segment of the graph, representing tangents with the same head width, was then calculated to determine the average tangent head widths given in table 4.9 below. The average tangent head width of these seven instruments are not, I believe, different by design but rather by accident, since they do not correlate exactly

[11] John Barnes has suggested that this board may have been intended as a dust catcher.

with the different bridge-pin spacings or with the hitchpin spacings. The arithmetical means are, however, close to $^4/_{24}$ (3.98mm), $^5/_{24}$ (4.98mm), $^6/_{24}$ (5.97mm) and $^7/_{24}$ (6.96mm) Zoll. The actual head-width measurements of each tangent of these clavichords is given as appendix 5.

**Table 4.9**
**Tangent head widths (in mm)**

| C to $d^3$ 1740b HH | | FF to $d^3$ 1732b HH | | GG to $d^3$ 1748 JH | |
|---|---|---|---|---|---|
| | | $f^2$ to $d^3$ | 4.0 | | |
| $d^2$ to $d^3$ | 5.0 | f to $e^2$ | 4.7 | f to $d^3$ | 4.4 |
| $e^b$ to $c^{\#2}$ | 5.6 | C to e | 5.7 | $G^\#$ to e | 5.7 |
| C to d | 7.1 | FF to BB | 6.8 | GG to G | 6.7 |

FF to $f^3$

| 1742a HH | | 1742b HH | | 1760b JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|
| $c^3$ to $f^3$ | 4.0 | $c^{\#3}$ to $f^3$ | 3.8 | $c^{\#3}$ to $f^3$ | 4.2 | $d^3$ to $f^3$ | 4.2 |
| f to $b^2$ | 4.8 | f to $c^3$ | 4.7 | $f^\#$ to $c^3$ | 4.8 | f to $c^{\#3}$ | 4.7 |
| C to e | 5.6 | BB to e | 5.5 | C to f | 6.1 | BB to e | 5.9 |
| FF to BB | 6.6 | FF to $BB^b$ | 6.2 | FF to BB | 7.5 | FF to $BB^b$ | 7.4 |

Each tangent protrudes about $^5/_6$ Zoll (nominally 19.9mm) above the top of all the keylevers of C to $d^3$ instruments and 1 Zoll (nominally 23.9mm) above the top of all the keylevers of FF to $f^3$ instruments. The depth of touch, or the distance needed for the near end of the natural head to descend to enable the tangent to strike its course of strings, is approximately twice as great in the bass as it is in the treble. This is because the tangents are further from the balance point in the treble than they are in the bass. The depth of touch of only two Hass clavichords and one Gerlach clavichord, which still have their original back touchrail cloths intact, have been measured. These are given in table 4.10 below:

**Table 4.10 The depth of touch (in mm)**

| | FF | F | f | $f^1$ | $f^2$ | $f^3$ |
|---|---|---|---|---|---|---|
| 1743b HH | 5 | 4 | 4 | 3½ | 3 | 2 |
| 1763a JH[12] | 4 | 5 | 5 | 4 | 3½ | 2½ |
| 1756 JG | 5½ | 4 | 3½ | 3 | 3 | $c^3$ 2½ |

## THE SOUNDBOARD

Soundboards of Hass clavichords are made from a white coniferous wood, probably spruce (*Picea sp.*). Although this wood has not been microscopically identified, the presence of pitchpockets on the underside of some boards confirms spruce as the most likely woodtype because the only other white coniferous wood possibility, fir (*Abies alba*), doesn't have pitchpockets. Each soundboard is usually made up from four pieces of wood butt-jointed together along their length, with the grain running parallel to the spine. A small internal liner, with an ogee moulding made with the same cutter as the case-top moulding, surrounds the edge of the soundboard, except along its left-hand edge where the board is glued to the treble keywell brace. Here the board overhangs the brace by some 3½mm. In all but one case, the 1767 JH, the left-hand edge of the soundboard is straight. In the case of the 1767 JH, however, the left-hand edge of the soundboard follows a meander-like pattern. There is an extra block of coniferous wood glued to the left-hand side of the treble brace, which is cut in an irregular meander-like fashion. The left-hand edge of the soundboard is cut parallel to this curved edge and not to the straight edge of the treble keywell brace proper.

The area of a soundboard determines the efficiency to which the soundboard is able to radiate the vibrations transmitted from the strings,[13] and it is significant that the soundboards of Hass clavichords are considerably larger than those of many other

12 The depth of touch of the bottom key of the 1763a JH is smaller now than originally because of warpage occuring subsequent to the original construction of the instrument.

makers. The soundboard area of the anonymous c.1700 German fretted C/E to $c^3$ clavichord at the Russell Collection[14] has an area of only 1027cm$^2$, for example, whilst the soundboard area of the C to $f^3$ fretted clavichord made by Hubert in 1784[15] is only 1526cm$^2$. This compares to a soundboard area of some 2562cm$^2$ for the C to $d^3$ (1725) HH clavichord. Furthermore, the soundboards of later Hieronymus and Johann Hass clavichords are generally larger than those made at the beginning of their careers, as shown in table 4.11 below:

**Table 4.11 Soundboard areas (cm$^2$)**

| C to $d^3$ | | FF to $f^3$ | | GG to $d^3$ | |
|---|---|---|---|---|---|
| (1725) HH | 2562 | 1742a HH | 3420 | 1748 JH | 3640 |
| 1740a HH | 2673 | 1742b HH | 3459 | | |
| 1740b HH | 2667 | 1744a HH | 3508 | | |
| 1746 JH | 3004 | 1747 JH | 3624 | | |
| 1761b JH | 3000 | 1755 JH | 3610 | | |
| | | 1763a JH | 3660 | | |

After the soundboard had been planed to its desired thickness and before the soundbars and bridges were glued in place, a series of lines was scribed onto the upper surface of the soundboard which are still clearly visible. A set of lines was scribed for the 8ft tuning pins and a single line was scribed for the 4ft hitchpins. All C to $d^3$ models have a single pair of lines for the 8ft tuning pins scribed perpendicularly to the right-hand end and diagonally at approximately 60° to the right-hand end. Although these lines correlate to the two sections of the 8ft wrestplank, the diagonally-scribed lines of C to $d^3$ models are not straight but rather form a

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13 My research into the efficiency of Hass soundboards is given in chapter 5, pp.156-64.

14 Collection Number 21, Russell Collection, University of Edinburgh, Edinburgh.

15 Collection Number 38, Russell Collection, University of Edinburgh, Edinburgh.

gentle curve. Most standard five-octave FF to $f^3$ models have two pairs of straight lines scribed both perpendicularly and at 60° to the right-hand end, except in the very bass where there is a single pair of lines for the notes FF to GG. One otherwise standard FF to $f^3$ instrument, the 1743a HH, has a single pair of lines for the notes FF to GG#. Only three standard five-octave instruments, the 1742a HH, the 1742b HH and the 1743b HH have two pairs of scribed lines throughout. Both the FF to $d^3$ 1732b HH and the GG to $d^3$ 1748 JH have two pairs of scribed lines for the 8ft tuning pins, except in the bass where there is only a single pair of lines. The single pair of lines is for the notes FF to $B^b$ and GG to GG# for the 1732b HH and the 1748 JH respectively. Only the tri-chord strung 1761a JH differs markedly from the standard arrangement, with three scribed lines for the 8ft tuning pins, except in the bass where there is a pair of lines for the notes FF to GG. In all Hass clavichords the single line for the 4ft hitchpins was scribed at 60° to the right-hand end of the case.

**SOUNDBOARD BARRING: THE CUTOFF BAR AND THE 4FT HITCHPIN RAIL**

There are two pine soundbars glued to the underside of the soundboard and positioned approximately parallel to the 4ft bridge. One soundbar is located between the 4ft bridge and the case front and serves as a cutoff bar, and the other is located between the two bridges and serves as a hitchpin rail for the 4ft hitchpins (see plate 4.3). The ends of both soundbars are scalloped and fitted into cutouts in the soundboard front liner and the treble keywell brace.

Hitchpins for the 4ft strings are made from brass wire 1.4mm thick and must have been positioned with the help of the diagonally-scribed line on the soundboard. Since the 4ft bridge is usually at about 55½° to the right-hand end of the case the line of the 4ft hitchpins is angled towards the 4ft bridge at the top note and away from the bridge at the bottom note.

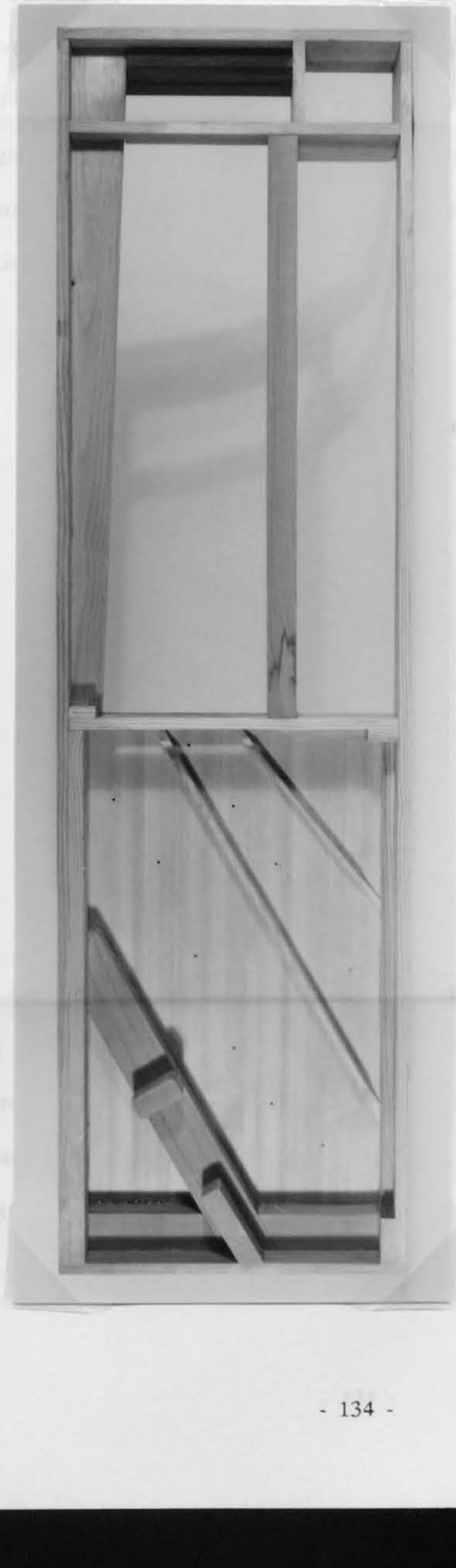
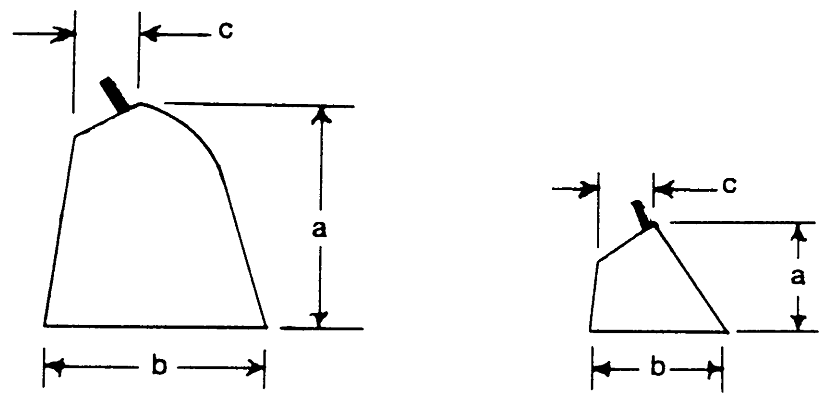


**Plate 4.3**
**Internal construction and soundboard barring of a C to $d^3$ clavichord**
(modern copy by the author)

## THE 8FT AND 4FT BRIDGES

Both the 8ft and 4ft bridges are always sawn from beech (*Fagus sylvatica*), a woodtype easily identifiable by the presence of rays, especially on longitudinal surfaces, where they appear as chocolate-brown lines or flecks. The two bridges vary in both overall shape, cross-section and size: the 8ft bridge has an 's'-shaped curve, a rounded leading edge and an angled following edge; the smaller 4ft bridge is usually straight and has angled surfaces. Only the (1725) HH and the 1728 HH have slightly curved 4ft bridges. Figure 4.11 below shows both the 8ft and 4ft bridges in cross-section.

**Figure 4.11**
**The 8ft and 4ft bridge sections**
(Scale 1:2)




8ft bridge 4ft bridge

Both the 8ft and the 4ft bridges taper in cross section from the bass to the treble, as shown in table 4.12. The heavier bass ends of the bridges have a larger contact area with the soundboard than the lighter treble ends, which means that the thicker bass strings can set a relatively larger area of the soundboard in motion than that required for the thinner treble strings.

**Table 4.12 Bridge dimensions**

The 8ft bridge

| | (1725) HH | | | | | 1742b HH | | | | | 1760b JH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | c | $c^2$ | $d^3$ | | FF | c | $c^2$ | $f^3$ | | FF | c | $c^2$ | $f^3$ |
| a | 13.3 | 14.1 | 13.7 | 12.4 | a | 14.4 | 13.0 | 12.5 | 12.8 | a | 14.2 | 13.7 | 12.0 | 12.1 |
| b | 15.5 | 15.0 | 12.3 | 12.2 | b | 23.0 | 15.7 | 15.0 | 13.4 | b | 17.5 | 16.0 | 15.6 | 12.8 |
| c | 4.0 | 3.7 | 3.3 | 3.2 | c | 5.9 | 4.8 | 4.0 | 4.3 | c | 5.7 | 5.0 | 4.9 | 4.7 |

The 4ft bridge

| | (1725) HH | | | | 1742b HH | | | | 1760b JH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | F | d | | FF | C | d | | FF | C | d |
| a | 8.0 | 7.8 | 7.5 | a | 6.8 | 6.9 | 6.4 | a | 7.3 | 7.15 | 6.8 |
| b | 11.2 | 10.6 | 8.8 | b | 10.5 | 8.7 | 9.3 | b | 10.0 | 9.6 | 8.6 |
| c | 2.8 | 3.5 | 2.5 | c | 4.2 | 4.0 | 4.3 | c | 4.3 | 3.8 | 4.3 |

As already shown, the overall shape of the bridge is one of the factors influencing the string scalings. Since the 4ft bridge is normally straight, for example, the 4ft scalings of Hass clavichords are not at all Pythagorean. The treble 8ft scalings of Hass clavichords are Pythagorean, but not simply because the 8ft bridge is 's'-shaped. The rack-slot spacing pattern, the placement of the bridge, the spacing of the bridge pins and the shape of the bridge are interdependent factors which influence the length of the strings.

Since the 8ft bridge pins are very accurately positioned in the bridge, a rubbing of the tops of the bridge pins gives a good impression of the 's'-shaped curve of the bridge. A comparison of rubbings made of the tops of the 8ft bridge pins has revealed that all surviving C to $d^3$ clavichords of Hieronymus Hass have the same bridge shape, and all C to $d^3$ clavichords of Johann Hass have the same bridge shape which is slightly different from that of Hieronymus Hass. The 8ft bridges of Johann Hass C to $d^3$ models differ from those of his father only in that they are some 35mm longer, in order to accommodate the one extra pair of bridge pins required for the additional unfretted pair of strings. The effect this has on the 8ft scalings has already been shown in table 4.8, p.118.

In contrast to the C to $d^3$ clavichords, the bridge shape of the five-octave clavichords is less standardised. In total, Hieronymus Hass used at least three different bridge templates for his FF to $f^3$ models as well as a special template for the unique FF to $d^3$ 1732b HH, and Johann Hass used at least three different standard templates. The bridge shapes of the surviving Hass clavichords, except for the 1754 JH and the 1761d JH are given in table 4.13 below. Those clavichords also sharing a common rack-slot spacing pattern are marked with an asterisk.

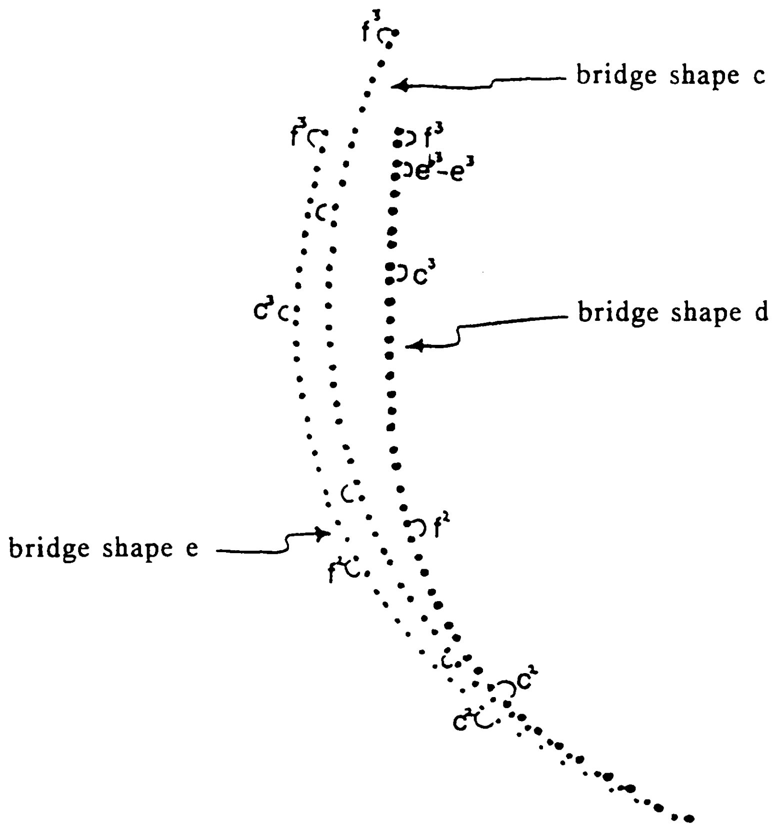
**Table 4.13**
**Instruments sharing the same 8ft bridge shape**

| Instrument | Compass | Shape |
|---|---|---|
| (1725)HH, 1728 HH,* 1740a HH, 1740b HH* | C to $d^3$ | a |
| 1732b HH | FF to $d^3$ | b |
| 1742a HH,* 1742b HH,* 1743b HH* | FF to $f^3$ | c |
| 1743a HH | FF to $f^3$ | d |
| 1744a HH, 1744b HH | FF to $f^3$ | e |

| Instrument | Compass | Shape |
|---|---|---|
| 1746 JH, 1756 JH,* 1761b JH* | C to $d^3$ | modified a |
| 1747 JH | FF to $f^3$ | f |
| 1748 JH | GG to $d^3$ | modified f |
| 1755 JH,* 1760b JH* | FF to $f^3$ | g |
| 1761c JH,* 1762 JH,* 1763a JH,* 1763b JH,* | FF to $f^3$ | h |
| 1761a JH (3 x 8ft) | FF to $f^3$ | modified $h^1$ |
| 1767 JH | FF to $f^3$ | modified $h^2$ |

The three main variables in the shape of the 8ft bridge of the FF to $f^3$ instruments are: the length of the central straight section; the degree of curvature of the bass end; and the degree of curvature of the treble end. The bridge shapes c, d and e are almost exactly the same in the bass, tenor and alto sections. These three shapes vary, however, in the treble part of the bridge from about the note $c^2$ upwards. The treble end of bridge shape c (represented by the 1742a HH, the 1742b HH and the 1743b HH), for example, is slightly longer than shapes d and e; and the treble end of shape d (represented by the 1743a HH only) is considerably straighter than types c and e. The actual treble curve of these three bridge shapes, derived from rubbings made of the tops of the bridge pins, is shown in figure 4.12.

**Figure 4.12**
**The treble curve of the bridge shapes c, d and e**
(Scale 1:1)




Johann Hass modified his FF to $f^3$ 8ft bridge template for the bridge of the GG to $d^3$ 1748 JH. Since the 1748 JH requires two less notes in the bass and three less notes in the treble than the five-octave FF to $f^3$ instruments, Hass simply truncated the ends of his FF to $f^3$ bridge shape. Johann Hass also modified his standard FF to $f^3$ template for the tri-chord strung 1761a JH. Hass started with his normal FF to $f^3$ template (shape h), but since the 1761a JH requires three fewer strings than standard FF to $f^3$ models Hass reduced the length of the central straight section of the bridge. He also made the treble curve of the 8ft bridge less pronounced.

It is difficult to apportion differences in the 8ft string scalings entirely to differences in the shape of the bridge, since there are no two Hass clavichords with the same rack-slot spacing pattern but with different bridge shapes. Although Hass sometimes changed the rack without changing the bridge shape (such as the two C to $d^3$ instruments surviving from 1740), he never changed the bridge shape without also changing the rack. Indeed, Hass seems always to have compensated for the changes he made to the curvature of the treble end of the 8ft bridge by either widening or narrowing the spacing of the treble rack slots in order that the treble scalings should work out to be the same.

Even when two or more clavichords have exactly the same bridge shape and rack-slot spacing the string scalings are never exactly the same. This can be illustrated by table 4.14 below, which gives the string scalings of the 1742a HH, the 1742b HH and the 1743b HH which all have the bridge shape c and the rack-slot spacing pattern e. The slight differences in these string scalings seems to imply that, whatever the method of marking out used by the Hass family was, it involved a system which aimed at certain nominal string scaling values, but gave priority to the exact physical placement of the strings and therefore to the mechanical functioning of the instrument.

**Table 4.14**
**The 8ft string scalings of the 1742a HH, 1742b HH and 1743b HH**
**(three instruments with the same rack-slot spacing pattern and bridge shape)**

| | 1742a HH | 1742b HH | 1743b HH | |
|---|---|---|---|---|
| $f^3$ | 105 | 106 | 105 | $f^3$ |
| $c^3$ | 141 | 143 | 139 | $c^3$ |
| $f^2$ | 213 | 215 | 210 | $f^2$ |
| $c^2$ | 284 | 286 | 282 | $c^2$ |
| $f^1$ | 426 | 424 | 421 | $f^1$ |
| $c^1$ | 570 | 569 | 564 | $c^1$ |
| f | 813 | 824 | 807 | f |
| c | 986 | 1004 | 985 | c |
| F | 1189 | 1205 | 1197 | F |
| C | 1304 | 1316 | 1318 | C |
| FF | 1445 | 1453 | 1458 | FF |

The positioning of the bridges on the soundboard is only theoretical because there are no construction marks either side of the bridges. However, since the top three c's ($c^3$, $c^2$ and $c^1$) have the smallest rms deviation, the treble end of the 8ft bridge may have been located in a similar way as that outlined by Tannenberg,[16] that is with the help of three marks made on the soundboard which represented the nominal string lengths for the three top c's. These marks could have been made by measuring out 6, 12 and 24 Zolle from approximate tangent positions to the soundboard and making a mark with a bradawl. If these marks were then enlarged into a hole they could have been used as starting holes to nail the bridges from the underside, without danger of breaking through the soundboard. Since the bass 8ft scalings are more variable than the treble scalings, it is possible that the bass end of the bridge was located relative to the right-hand case end. Indeed, the bottom 8ft bridge pin is always very close to 6 Zolle (nominally 143.2mm) from the inside right-hand case end regardless of maker or compass of the instrument.

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16 T. McGeary, "David Tannenberg and the Clavichord in Eighteenth-Century America," *The Organ Yearbook*, XIII (1982), pp.103 & 105.

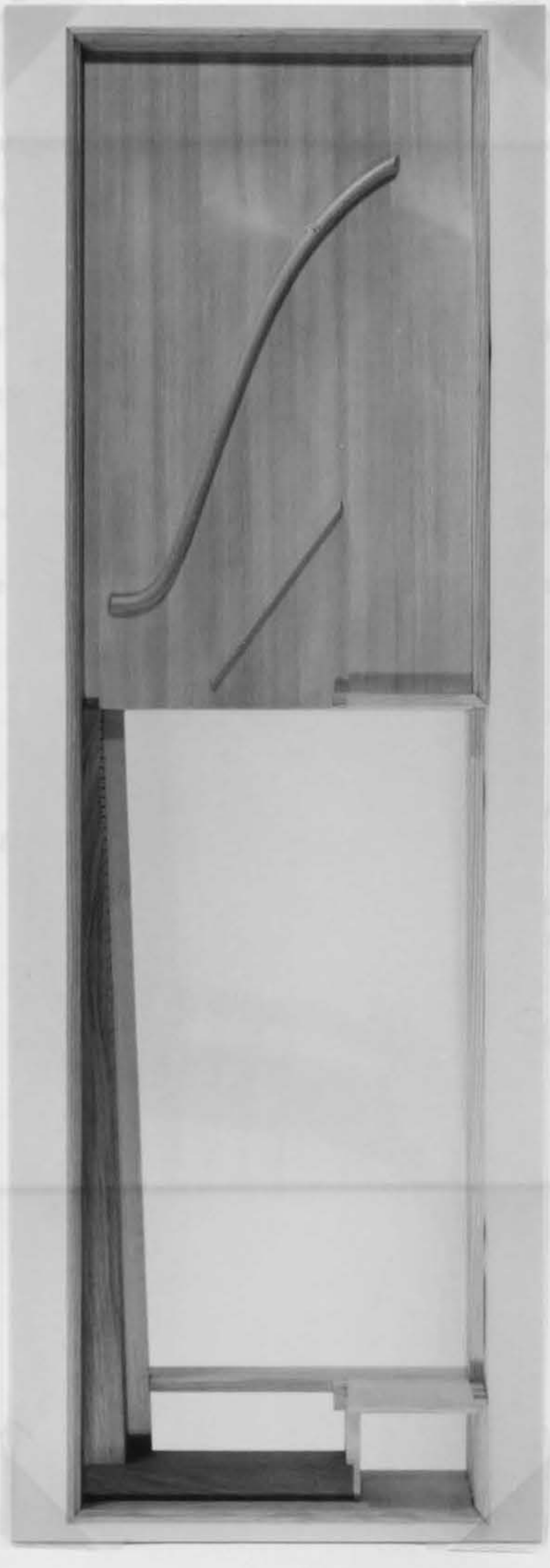

**Plate 4.4**
**The soundboard layout of a C to $d^3$ clavichord**
(modern copy by the author)

The orientation of the 8ft bridge of FF to $f^3$ clavichords varies between instruments constructed in different years. This is because both Hieronymus and Johann Hass kept the bass end of the bridge at a constant distance from the right-hand end, but increased the distance of the treble end from the right-hand end chronologically with the date of construction. This ensured that the treble scalings could be kept constant while at the same time lengthening the bass scalings. It is this change in the orientation of the bridge which may partly explain changes in the shape of the bridge. This concept can be illustrated by comparing the bridge shape, the orientation of the bridge, the rack-slot spacing and the string scalings of two five-octave clavichords, the 1755 JH and the 1763a JH. The 8ft scalings of the two instruments, together with the distance of each near pin of a pair of 8ft bridge pins for all the f's and c's are given in table 4.15. Table 4.16 shows the distance (in mm) between each successive f and c rack slots for the two instruments.

**Table 4.15**
**The 8ft string scalings and the orientation of the 8ft bridge relative to the right-hand end of the 1755 JH and the 1763a JH**

| | 8ft string scalings (in mm) | | Distance of bridge pins from right-hand end (in mm) | | | |
|---|---|---|---|---|---|---|
| | 1755 JH | 1763a JH | 1755 JH | 1763a JH | Difference | |
| $f^3$ | 105 | 104 | 666 | 679 | 13 | $f^3$ |
| $c^3$ | 144 | 140 | 677 | 694 | 17 | $c^3$ |
| $f^2$ | 212 | 212 | 679 | 703 | 24 | $f^2$ |
| $c^2$ | 283 | 285 | 672 | 700 | 28 | $c^2$ |
| $f^1$ | 420 | 426 | 632 | 660 | 28 | $f^1$ |
| $c^1$ | 566 | 568 | 568 | 591 | 23 | $c^1$ |
| f | 811 | 837 | 434 | 430 | 4 | f |
| c | 988 | 1022 | 353 | 323 | 30 | c |
| F | 1195 | 1215 | 247 | 230 | 17 | F |
| C | 1315 | 1323 | 196 | 190 | 6 | C |
| FF | 1470 | 1471 | 149 | 149 | 0 | FF |

**Table 4.16**
**Basic rack-slot spacings for the 1755 JH and the 1763a JH (in mm)**

| | 1755 JH | 1763a JH |
|---|---|---|
| $c^3$-$f^3$ | 43 | 49 |
| $f^2$-$c^3$ | 72 | 80 |
| $c^2$-$f^2$ | 62 | 68 |
| $f^1$-$c^2$ | 99 | 101 |
| $c^1$-$f^1$ | 78½ | 73 |
| f-$c^1$ | 121 | 108½ |
| c-f | 88 | 76½ |
| F-c | 98 | 99 |
| C-F | 70½ | 72 |
| FF-C | 98 | 100 |

Although the treble ends of the 8ft bridges of these two instruments are positioned differently relative to the right-hand case end, the treble scalings are in fact very similar. This is because slight differences in the shape of the bridge in this part of the compass (see figure 4.13) are compensated for by differences in the rack-slot spacing. In the very bass the scalings are virtually identical because the bass end of the two bridges is positioned the same distance from the right-hand case end, and the entire rack-slot span of the two instruments is only 3mm different. The largest discrepancy in the scalings occurs in the tenor section of the compass (from C to f), where the differences in the curvature of the bridge (see figure 4.14) are shown up as both differences in the distance of the bridge pins from the inside of the right-hand case end, and in the string scalings.

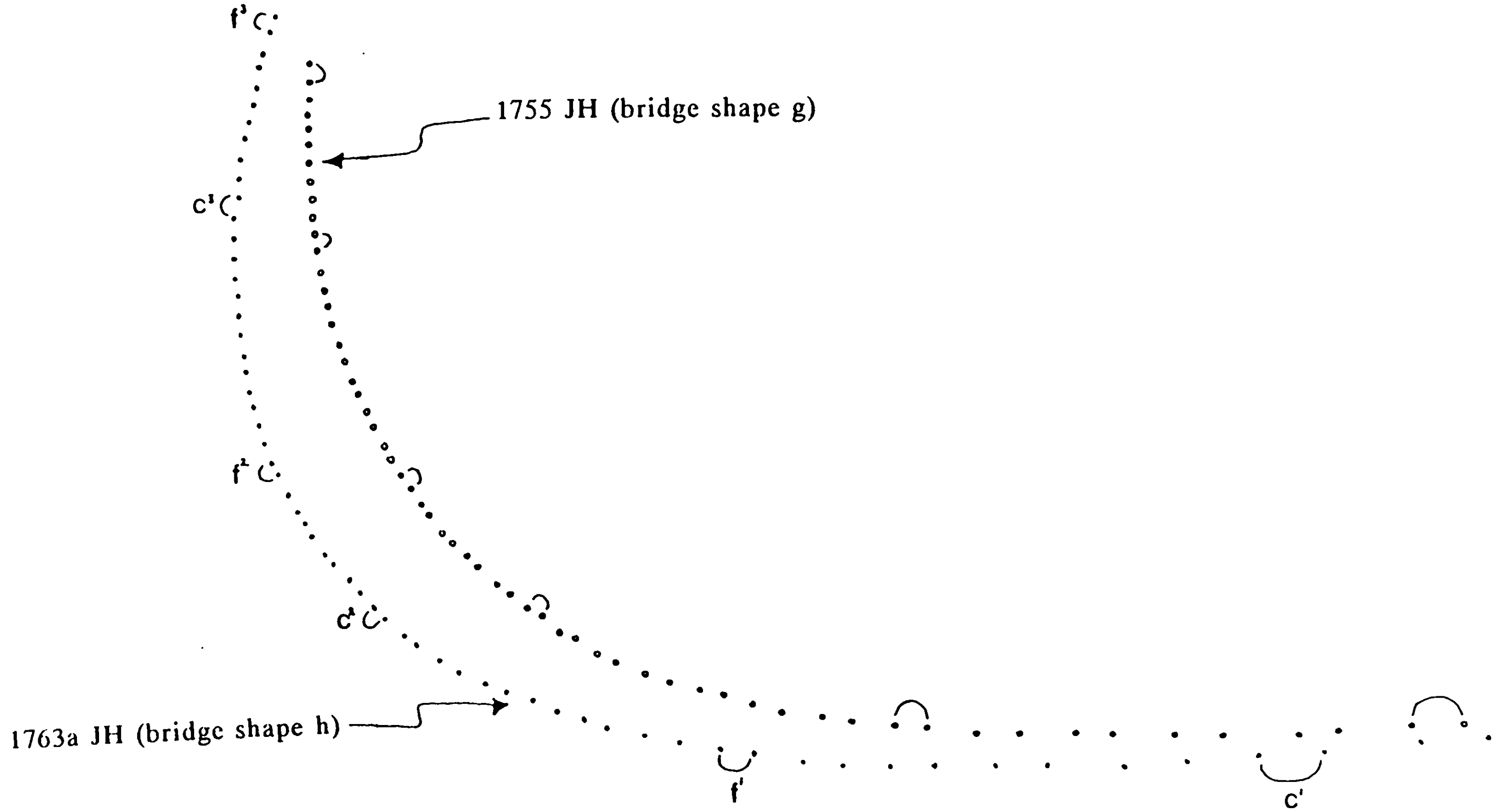


**Figure 4.13**
**A comparison of the treble ends of the 8ft bridge of the 1755 JH and the 1763a JH**
(Scale 1:1)

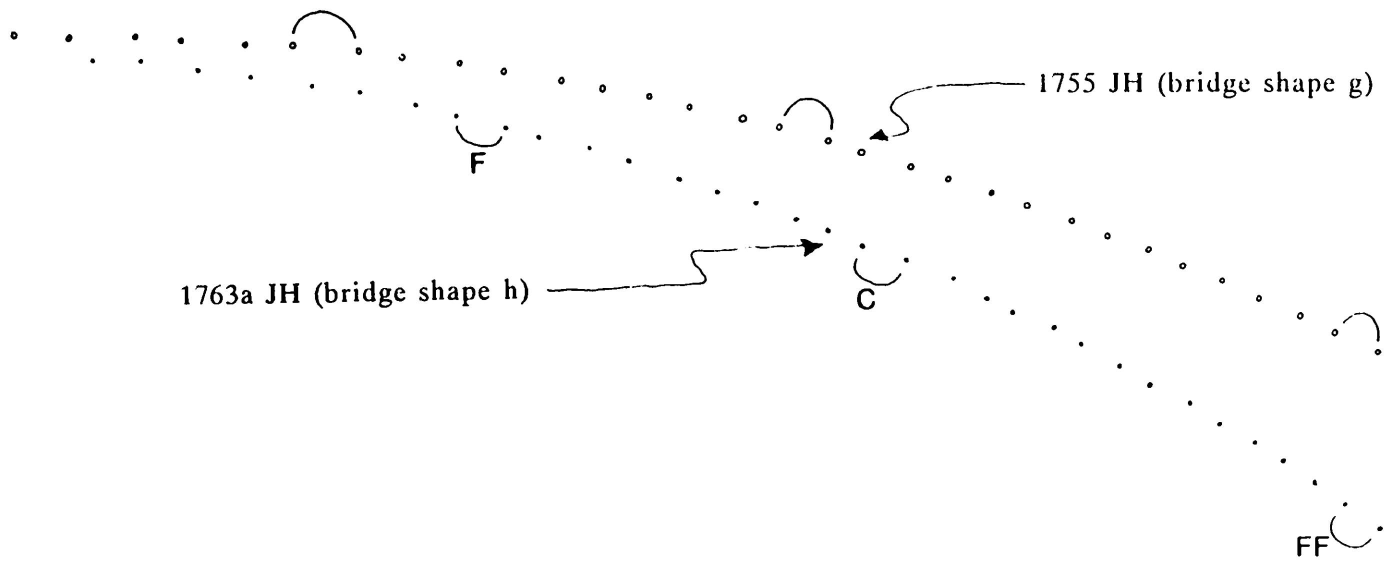


**Figure 4.14**
**A comparison of the bass ends of the 8ft bridge of the 1755 JH and the 1763a JH**
(Scale 1:1)

Since the 4ft bridge is straight it can be positioned relatively easily using either end. The top note, d, of all Hieronymus Hass models has a string length of 24 Zolle (nominally 573.0mm), while the bottom string is either 39½ Zolle (nominally 943.0mm) in the case of C to $d^3$ models or 46 Zolle (nominally 1098.2mm) for the FF to $f^3$ models. It is likely, therefore, that Hass located the 4ft bridge using the approximate tangent positions and these nominal string lengths in the same way as already explained for the location of the 8ft bridge. Regardless of model, the angle of the 4ft bridge of Hieronymus Hass clavichords is always very close to 55½° to the right-hand case end. The position of the 4ft bridge of Johann Hass clavichords is less standard. In cases where the top note is d, this note can have a string length of between 23½ and 25 Zolle (nominally 561.0mm and 596.9mm respectively), while the bottom string is either 39½ Zolle (nominally 943.0mm) for C to $d^3$ models or 47 Zolle (nominally 1122.1mm) for FF to $f^3$ models. The angle of the bridge is, however, still always close to 55½°. The 4ft bridge of instruments made after 1761, with either c or B as the top note, is positioned at a slightly different angle: the bridge of the 1763 JH is, for example, positioned at 59° to the right-hand end, with a top and bottom string length of 26 and $46^3/_4$ Zolle (nominally 620.7 and 1116.1mm respectively).

Whilst the bridges were being glued to the soundboard go-bars were probably used to exert downward pressure onto the bridges. The method used to prevent the bridges from sliding away from their correct orientation is not known for certain, but there is no indication that Hass used positioning nails either side of the bridge. The bridges could, perhaps, have been held in position by using the 8ft bridge template as a guide clamped alongside the bridge, or by using wooden blocks clamped at strategic points along the bridge, or by using the nails driven into the soundboard from the underside.

## THE 8FT AND 4FT BRIDGE PINS

The bridge pins are made from brass wire, which is 1.1 to 1.3mm thick for the 8ft pins and 1.0mm thick for the 4ft pins. After the pins were positioned they were slightly angled towards the case front and the tops then filed flat. The 8ft bridge of most Hieronymus Hass FF to $f^3$ models, as well as the 1747 JH and 1755 JH, is backpinned from FF to BB to create some degree of sidedraft. There are exceptions to this: the 1742a HH is backpinned from FF to E, the 1748 JH is backpinned from GG to e and the 1732b HH was originally backpinned from FF to e. The backpins themselves are made from the same wire as the normal bridge pins, but are slightly angled towards the spine rather than towards the case front. It is difficult, however, to tune strings through backpins, and perhaps because of this all Johann Hass instruments from the 1760's are not backpinned.

## THE TOOLBOX

Like most clavichord builders Hass provided his instruments with a small toolbox at the bass end of the keywell. The toolbox utilises the enclosed space between the front left-hand case corner and the left-hand keywell brace. The rear surface of the toolbox is formed by a small rectangular-shaped piece of pine, known as the toolbox backing piece, which is jointed to the near end of the 4ft wrestplank. The space is enclosed by a small oak lid, pivoted along the edge nearest the player by a thin brass rod about 2mm thick. The top surface of the toolbox lid is constructed as a raised panel. Only the toolbox of the 1742b HH survives with an original toolbox lock, which is fitted into the rear surface of the toolbox backing piece. The original key to the toolbox lock of this instrument also survives.

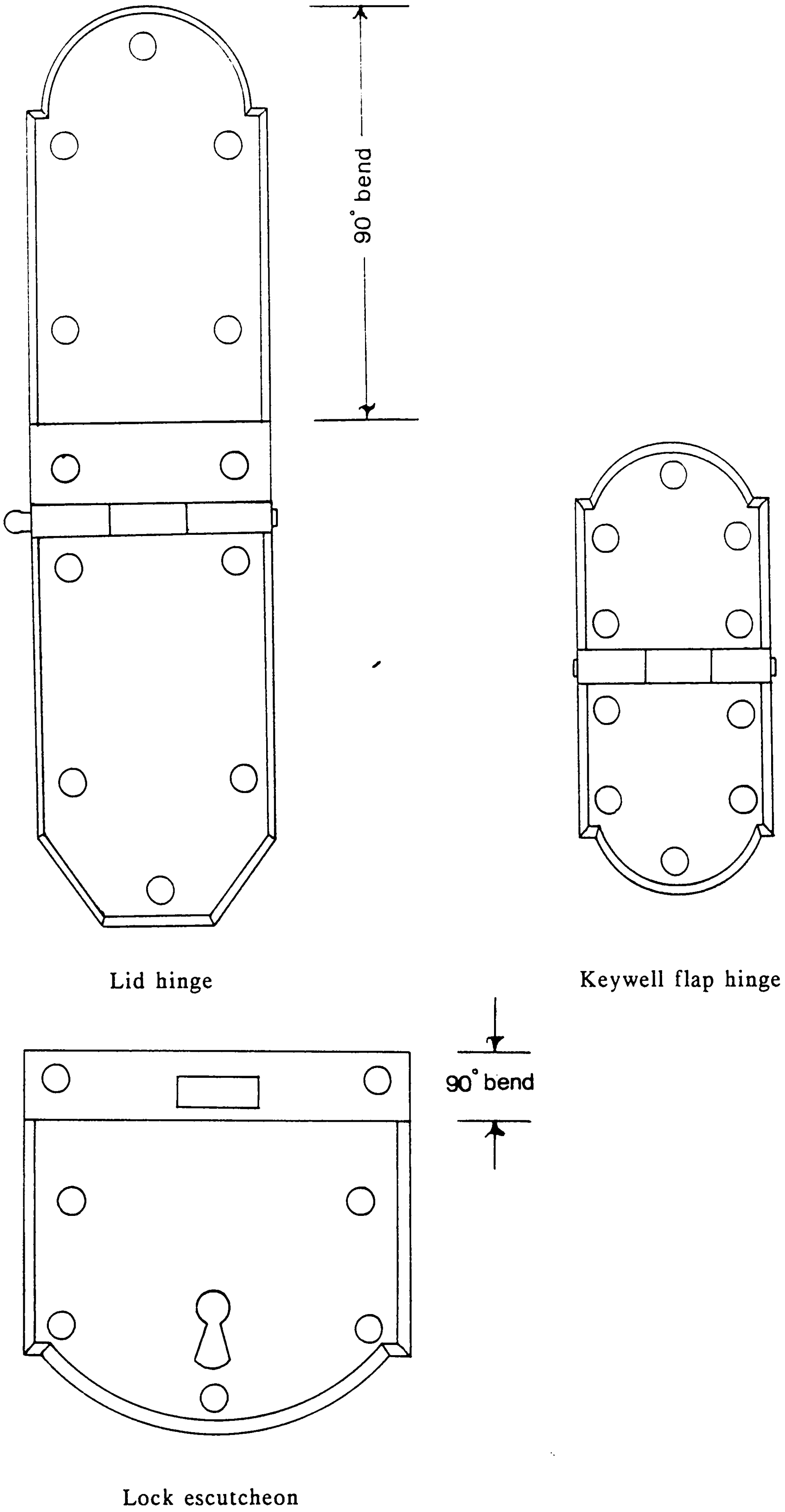


**Figure 4.15**
**Standard brassware** (Scale 1:1)

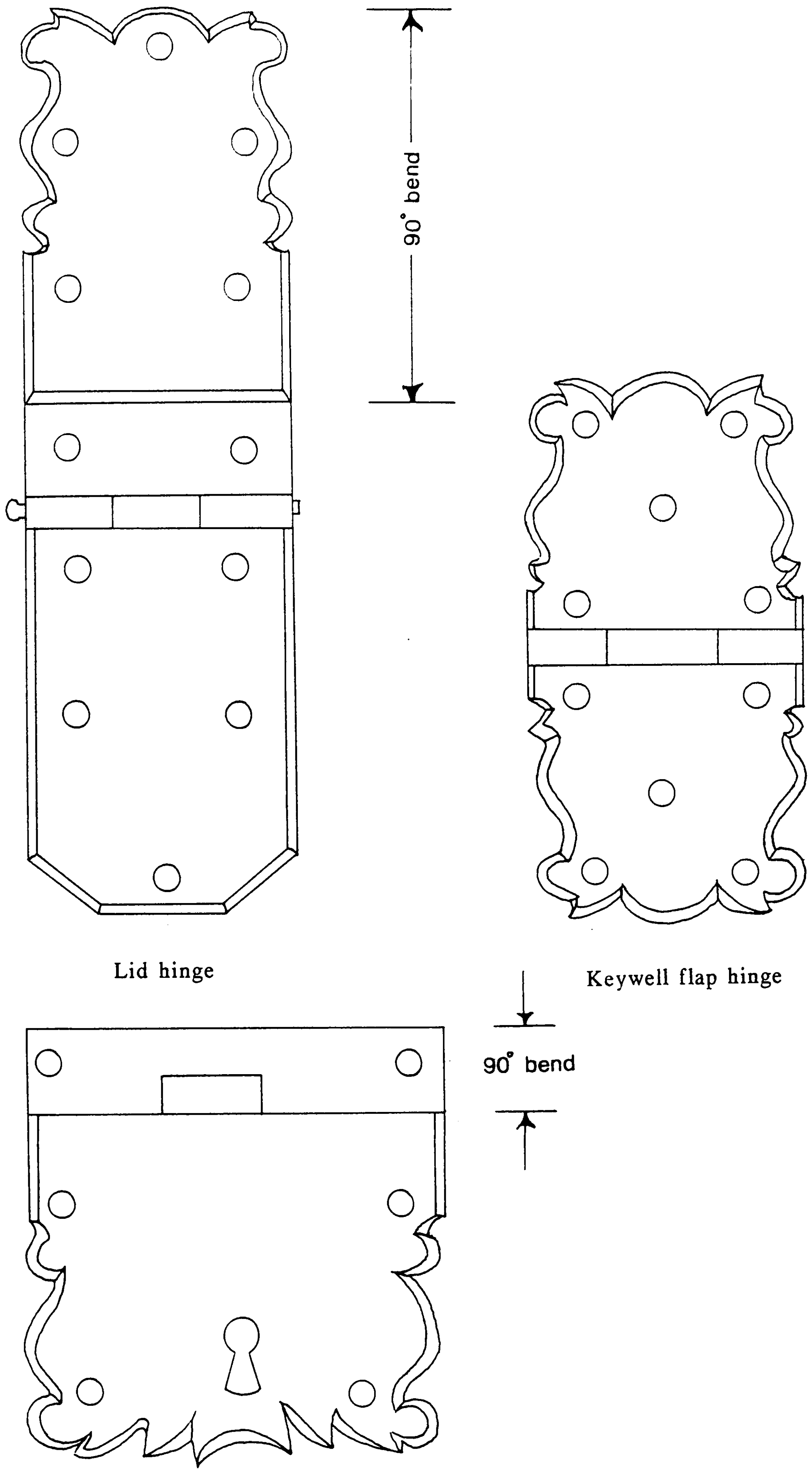


**Figure 4.16**
**Unique brassware of the 1763a JH** (Scale 1:1)

## THE KEYWELL FLAP

Like the case sides the keywell flap is probably made from Scots pine. There is the usual case-top moulding along the top edge of the keywell flap, so that when raised the keywell flap completes the case. This same moulding is also worked into the bottom edge of the keywell flap so that when lowered the flap also matches the case sides. The keywell flap is attached to the case front with either three wire hinges or with two brass strapwork hinges. The (1725) HH, the 1728 HH, the 1732b HH, the 1740b HH and the 1743b HH have simple wire hinges and all other instruments have brass strapwork hinges. When the keywell flap is raised a brass lock (usually fitted centrally into the front of the flap) enables the keywell flap to be secured to the main lid. The brass strapwork hinges (see figure 4.15 for the standard brassware and table 4.16 for the unique brassware of the 1763a JH) are secured in place with brass tacks, five tacks into the keyflap and five into the front of the case. The heads of all the tacks have been filed so that they are flush with the surface of the hinge.

## THE LID

Lids of Hass clavichords are made from three planks of coniferous wood, which is probably Scots pine. The planks are butt-jointed together along their length such that the grain of the lid runs parallel to the spine of the case. Although the spine edge of the lid is left straight the front edge of the lid is always rounded. The ends of the lid, which overhang the case sides by 15 to 30mm, are strengthened in most cases by a moulded batten. Since the grain of the end battens runs at right-angles to the grain direction of the main lid they prevent the lid from warping. The battens, which are also made from pine, are attached to either end of the lid with a barefaced tongue-and-groove joint (see figure 4.17). Only the 1763a JH and the 1767 JH do not have these moulded end battens. Instead, the lids of both these instruments are prevented from warping by a simple end batten, which is secured with a standard tongue-and-groove joint (see figure 4.18).

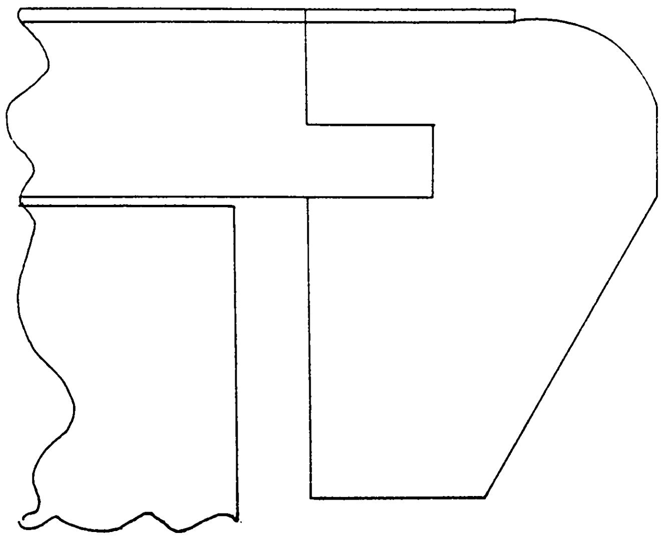

**Figure 4.17**
**The moulded end battens on the lid of most clavichords**
Scale 2:1

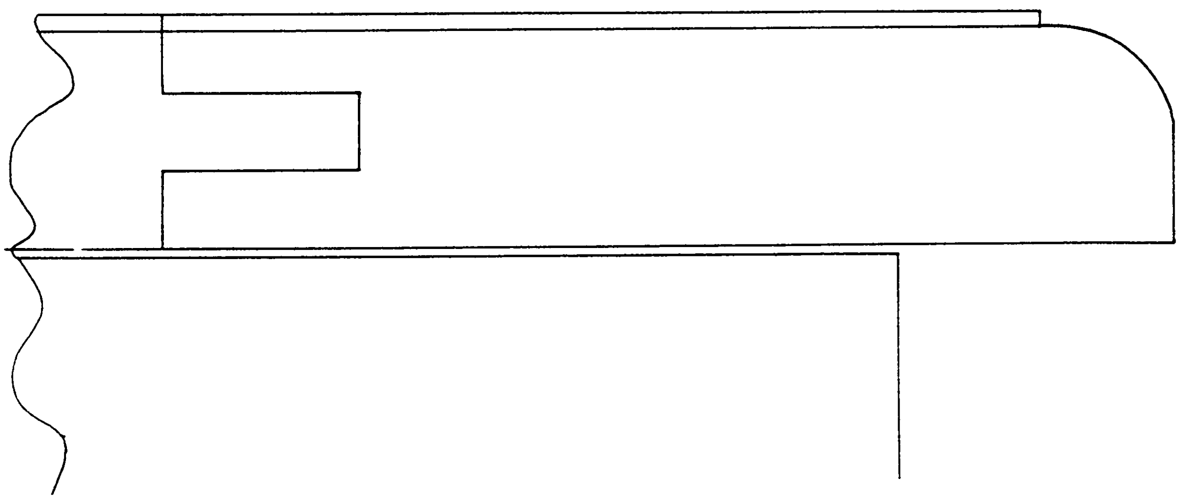

**Figure 4.18**
**The end battens on the lid of the 1763a JH and the 1767 JH**
Scale 2:1

The lid is attached to the spine of the case with three brass strapwork hinges (see figures 4.15 and 4.16). Each of the hinges is secured in place with brass tacks and a single dome-headed brass rivet. There are five tacks into the face of the lid, two into the spine edge of the lid and five into the spine. The brass rivet is driven through the hinge and the spine of the clavichord from the inside of the case. The axle pin of the hinge is turned iron and has a spherical stop knob at one end.

Lids of all Hass clavichords overhang the case front by 10-20mm and are held open by a cord. This cord is attached with two brass hoops, one in the lid and one in the 4ft wrestplank. The lid can be secured in its closed position with the aid of a brass hook on both the soundboard front and the toolbox front, their eyelets in the main lid, and the brass lock on the front of the keywell flap. The type of lock used is that normally found on small chests and boxes. The lock is housed in a recess in the keywell flap and has a matching locking plate that is let into the lid which is fitted with a single hook. This hook engages with a tooth that rises from the lock when the key is turned.

**THE STAND**

Only five instruments, the 1740a HH, 1744a HH, 1747 JH, the 1756 JH and the 1767 JH retain their original stands. The stand of the 1744a HH is typical of these and consists of four pine boards jointed together to form a rectangular frame 1740mm long by 539mm wide. Each corner of this frame is secured with a dovetail joint. A second board is glued to the inside surface of both end planks to give the frame added strength and also to provide a larger surface area on which the ends of the clavichord can rest. The front part of the frame, known as the apron, has a cutout for the player's knees and a drawer (probably for music, spare strings and tuning hammer) which is situated in the right-hand end of the apron. An added moulding surrounds the top edge of the apron and both ends of the frame. There is also an added moulding along the bottom edge of the frame except where there is the cutout for the player's knees. As well as being decorative the moulding which surrounds the top of the frame is also functional. By slightly overlapping three sides of the frame the top moulding creates a recess into which the clavichord fits. The frame is supported by four cabriole legs and stands $27^1/_3$ Zolle (nominally 652.6mm) high.[17]

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17 The cabriole legs (known in German as *Rehfüßen*) of both the 1740a HH and 1747 JH end in a cloven hoof.

# Chapter 5

## SOME PHYSICS OF THE CLAVICHORD

### KEYLEVER DESIGN

When a keylever is depressed, momentum (mass x velocity) is transferred from the player's finger to the string via the tangent. Since momentum is the product of mass and velocity, the velocity of the tangent is an important factor in determining the volume of sound produced. It is easy to play loudly in the bass, because the strings are thickest in this part of the compass and the keylevers have a relatively high mechanical advantage (see formula 1), but the treble tends to be weak. In order to try and balance the strength of the bass and treble tone, it is necessary for the treble tangents to be moving as fast as possible. Historical clavichord design ensures that this is the case by having the treble strings positioned further from the player than the bass strings, and therefore the tangents positioned further along the keylevers, which in turn ensures a higher tangent velocity (see formula 2) in the treble than in the bass.

Formula 1
<u>The mechanical advantage of the keylever</u>

$$\text{mechanical advantage} = \frac{a}{b}$$

Formula 2
<u>The tangent velocity</u>

$$\text{tangent velocity} = A \cdot \frac{b}{a}$$

where $a$ = distance from the balance point to the front of the key
$b$ = distance from the balance point to the tangent
$A$ = keyfront velocity

The distance of the keylever balance line from the front of the keylevers is an important aspect of clavichord design, and one which requires a degree of compromise on the part of the maker. The velocity of the tangent can be increased, for example, by moving the line of balance nearer to the front of the keylever, but if positioned too close the tangent tends to block or bounce off the strings. The balance line also determines whether or not the keylevers will fall back under their own weight. In this case if the balance line is moved too far away from the front of the keylever the keys will not fall back under their own weight, and will need to be either weighted in the tail with lead (which increases the inertia of the lever and slows the tangent), or the front of the keylever will need to be lightened by carving away the underside of the keyhead.

In all C to $d^3$ clavichords by both Hieronymus and Johann Hass the balance line of the natural keylevers is 5½ Zolle (nominally 131.3mm) from the front edge of the natural touchplates throughout the compass, and the balance line of the accidentals is ½ Zoll behind this. This distance is far enough from the front of the naturals to ensure that both the bass and treble keylevers fall back under their own weight, but not enough to cause the tangents to block. In contrast, the balance line of Hass five-octave FF to $f^3$ clavichords is positioned further from the player in the treble than in the bass: the natural balance line of the clavichords dating from the 1760's, for example, is positioned 7 Zolle (nominally 167.1mm) from the front of the natural for the note $f^3$ and 6½ Zolle (nominally 155.2mm) for the note FF; the balance line for the accidentals is $^3/_4$ Zoll (nominally 17.9mm) behind this. By angling the balance line in this way Hass is improving the mechanical advantage of the treble keylevers at the expense of their tangent velocity. The long treble keylevers of FF to $f^3$ clavichords, which need to pass under sixty-one string pairs instead of thirty-six or thirty-seven string pairs for C to $d^3$ clavichords, would be unplayable if their mechanical advantage was not improved in this way.

## THE LISTING CLOTH

The listing consists of several narrow strips of cloth, which is woven between successive courses of strings. Since this cloth is positioned towards the left-hand end of the strings, between the tangent and the 8ft hitchpins, it damps out the vibrations of the non-sounding part of the string. However, this is not the only function of the listing cloth. It is well known that a clavichord can be made to sound louder by striking the keyhead faster, but if struck too forcefully the string will stretch and sound out of tune. During normal playing the listing cloth can, if woven tightly, help prevent the strings from being stretched. The listing cloth also holds each course of strings together and so ensures that each tangent only strikes its own course.

## SOME ACOUSTICS OF HASS SOUNDBOARDS

The soundboard's function in a clavichord is to radiate the sound energy of the string vibrations. When a string is set in motion the vibrations travel down the length of the string to the bridge which transmits the energy to the soundboard. In response to these vibrations the soundboard oscillates up and down like a diaphragm, and causes a compression pulse to travel upwards in the air and the sound to be radiated. The degree to which the soundboard is able to respond effectively to the vibrations of the strings is dependent upon its physical characteristics: most importantly its area, but also its stiffness and to a lesser extent its mass. Obviously, the greatest response of the soundboard occurs when the frequency of the sounding note is equal to the natural resonance of the soundboard itself.

An attempt to gauge the effectiveness of Hass soundboards in response to different frequencies was made by recording the sound of various notes throughout the compass of the unfretted five-octave FF to $f^3$ 1763a JH (in the Russell Collection, University of Edinburgh) and running spectrum analysis. For comparative purposes various notes of the fretted C to $f^3$ clavichord made by Christian Gottlob Hubert of Ansbach in 1784 (Russell Collection No.38) were also analysed. Since the start of a clavichord note has a high proportion of unpitched sound from the percussive attack, in order to show a clear picture of the relative strengths of the string partials, data segments were delayed from the start by about 0.1 seconds for most notes and 0.2 seconds for the lowest notes. The data segments of the recorded sounds were fed into a computer which determined the number and relative strengths of the string partials, and then represented these components as a bar chart, with the height of each bar proportional to the amplitude of the corresponding partial. The frequency spectra for the notes C, $c^1$ and $f^3$ of both clavichords are shown in the charts 5.1, 5.2 and 5.3, and the frequency spectra for the note FF# of the 1763a JH is shown in chart 5.4.

Since the clavichord built in 1784 by Hubert has a soundboard area of only 1526cm$^2$ compared to a soundboard area of 3660 cm$^2$ for the clavichord built in 1763 by Johann Hass, spectra for the various notes over the full range of the two instruments show a marked contrast. Basically, the low notes of the Hass have strong low partials because of the relatively large soundboard, whereas those of the Hubert are not radiated because the soundboard is far too small in relation to the wavelengths. For the very lowest notes (from FF to about BB), however, even the soundboard of the Hass clavichord is too small for the frequencies involved: the note C, for example, has an impressive fundamental, but the FF# at 46 Hz is fairly deficient in both the first (46 Hz) and second partials (92 Hz). This is not really surprising, since the wavelength of the note FF# is about 7½m long, more than four times as long as the entire clavichord.

**Calculation of the wavelength for the note FF#**

$$\text{wavelength (lambda)} = \frac{\text{speed of sound}}{\text{frequency}}$$

$$\text{wavelength of FF}^{\#} = \frac{343\ \text{m/sec}}{46\ \text{/sec}} = 7.45\text{m}$$

For the very lowest frequencies it seems that the air resonance of the cavity beneath the soundboard may contribute to the sound of the 1763a JH, and perhaps all other Hass clavichords as well. For the note FF#, for instance, there is a broad peak in the spectrum in the vicinity of 60 to 65 Hz, which does not correspond to any of the string partials (see chart 5.4). Since it was not possible to experiment directly upon the 1763a JH investigations were carried out upon my Hieronymus Hass-type C to $d^3$ clavichord. The basic technique was to set the copy instrument in front of a loudspeaker, and play sine waves at various frequencies while observing the amplitude of signals from a small microphone positioned in the space beneath the soundboard. Since the air resonance beneath the soundboard and the wood resonance of the soundboard itself are closely coupled some care was needed to distinguish between them. This was done by altering the size of the mousehole since this only effects the frequency for air resonances and not for wood resonances. A clear Helmholtz-type resonance from the volume of air in the cavity beneath the soundboard was in fact found at 65 Hz with the mousehole (measuring 165mm long and 20mm high) fully open, 56 Hz with the mousehole reduced to a length of 94mm and 47 Hz with the window further reduced to a length of 51mm.

It is likely, therefore, that the main air resonance of the copy instrument is the same as that causing the peak in the spectrum of the note FF# of the 1763a JH. However, since the copy instrument only has a soundboard area of some 2640 $cm^2$ compared to a soundboard area of 3660 $cm^2$ for the 1763a JH, an attempt was made to calculate the air resonance frequency of both instruments. For a Helmholtz resonator of volume $V$, with a cylindrical neck of cross-sectional area $A$ and length $l$, the air in the neck behaves as a mass attached to a spring. The natural frequency of vibration is given by the formula:[1]

$$f_o = \frac{c}{2\pi} \left( \frac{A}{V\,l} \right)^{\frac{1}{2}}$$

where $c$ = the speed of sound = 343m/s

For the two clavichords

$A$ = area of mousehole
(copy instrument = $3.3 \times 10^{-3}$, 1763a JH = $4.8 \times 10^{-3}$)
$V$ = volume of air in cavity
(copy instrument $\approx 0.17467 m^3$, 1763a JH $\approx 0.32128 m^3$)
$l$ = depth of mousehole, or thickness of the treble keywell brace
(both clavichords $\approx 0.017$m)

This gave the following results:

<u>Copy Instrument</u>

$$f_o = \frac{343}{2\pi} \left( \frac{3.3 \times 10^{-3}}{1.75 \times 10^{-1} \times 1.7 \times 10^{-2}} \right)^{\frac{1}{2}}$$

$f_o$ = 57.49 Hz

<u>1763a JH</u>

$$f_o = \frac{343}{2\pi} \left( \frac{4.8 \times 10^{-3}}{3.21 \times 10^{-1} \times 1.7 \times 10^{-2}} \right)^{\frac{1}{2}}$$

$f_o$ = 51.2 Hz

The calculated air resonance of the copy instrument gives a poor match with the actual measured resonance, but this is not really surprising. The more-or-less retangular shape of both the cavity and the mousehole depart drastically from the ideal

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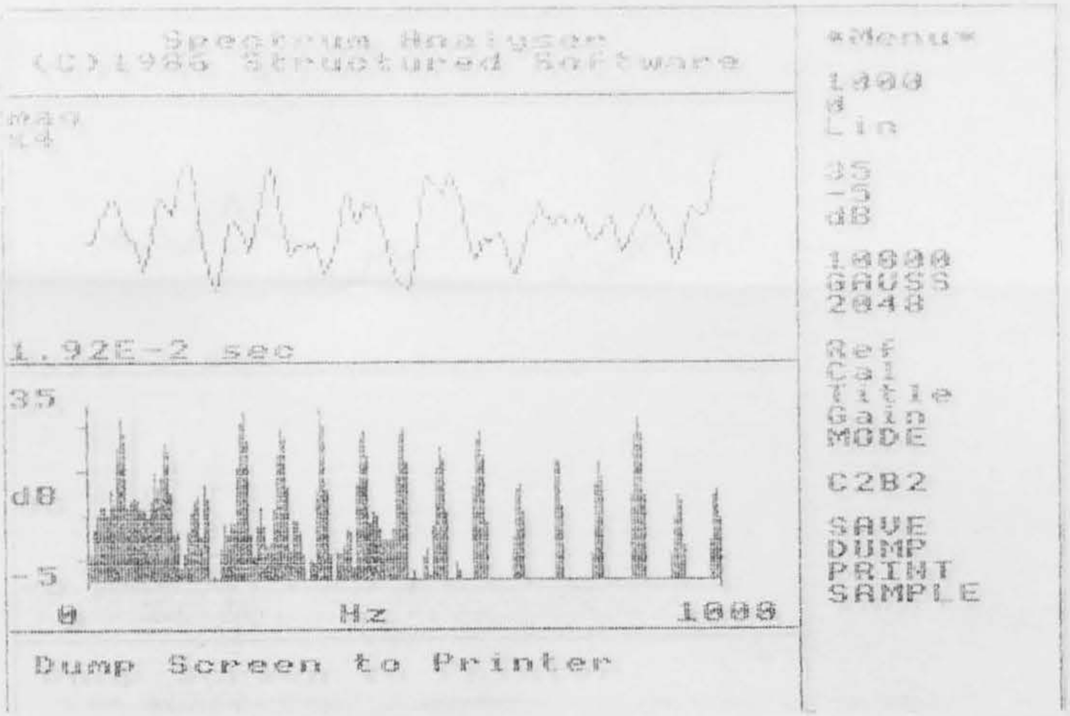
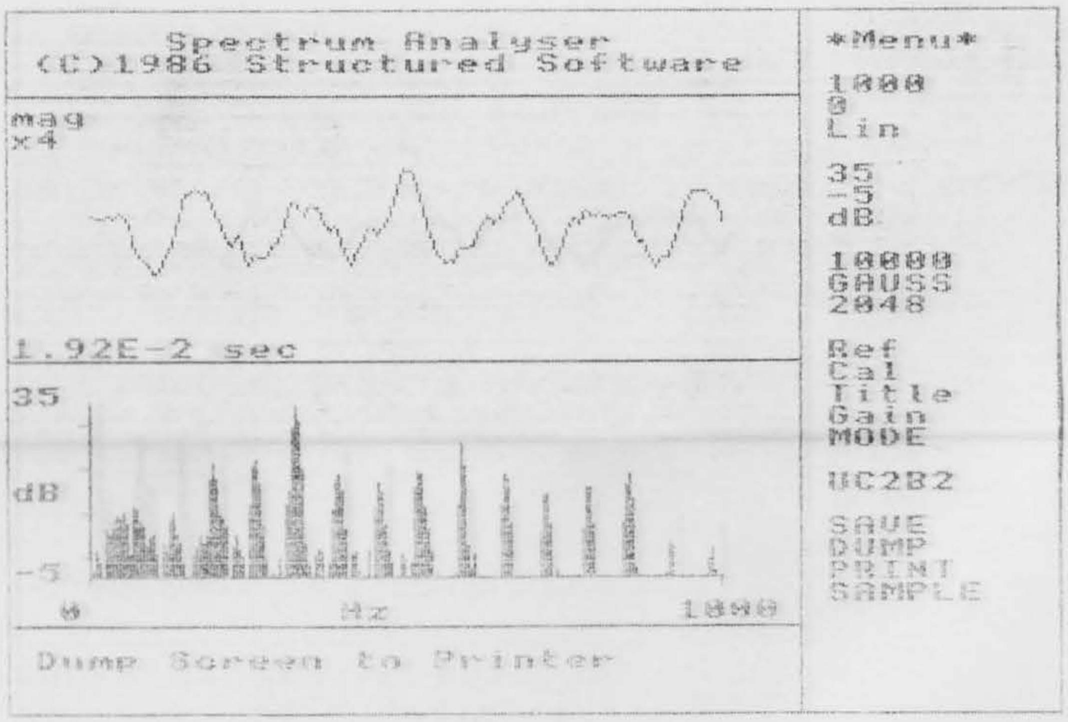
[1] N.H. Fletcher & T.D. Rossing, *The Physics of Musical Instruments* (New York: Springer, 1991), p.13.

model resembling a laboratory flask with a spherical volume and a long narrow neck. The calculations for the two instruments do, however, show that although the internal volume of the 1763a JH is larger than the copy instrument there is a similar air resonance because of the larger mousehole. Consequently, the broad peak in the spectrum of the note FF# of the 1763a JH at around 60 to 65 Hz is in fact probably due to a cavity resonance excited by the key attack.

**Chart 5.1**
**The frequency spectra for the note C**

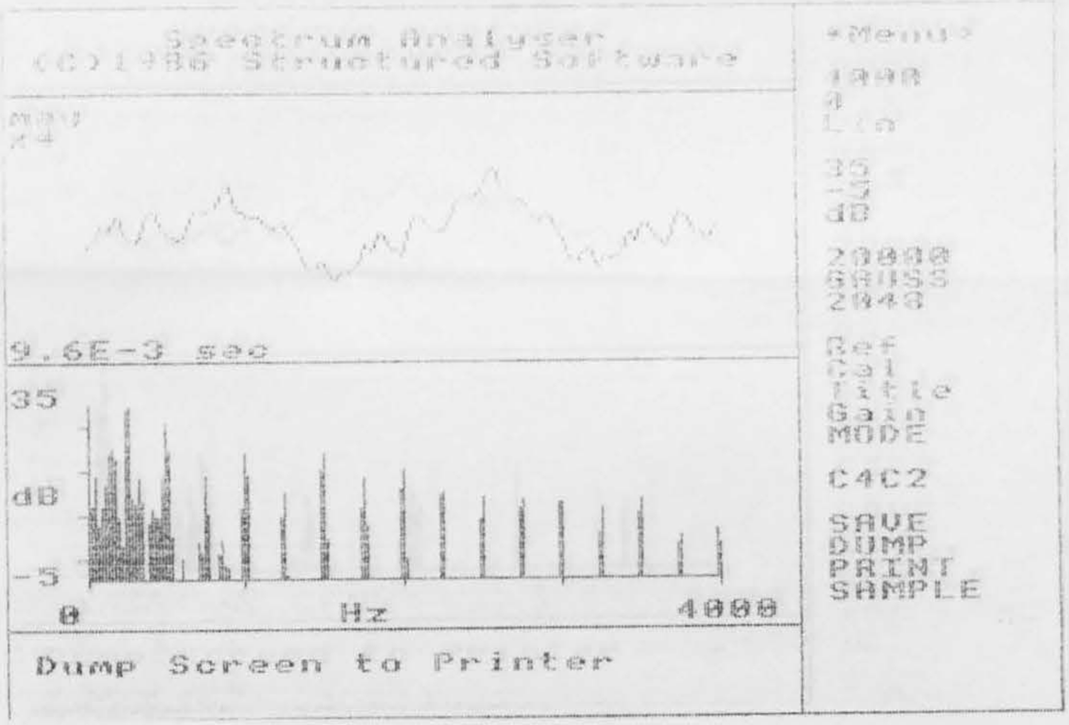



1763a J.A. Hass (delay 0.2 sec.)

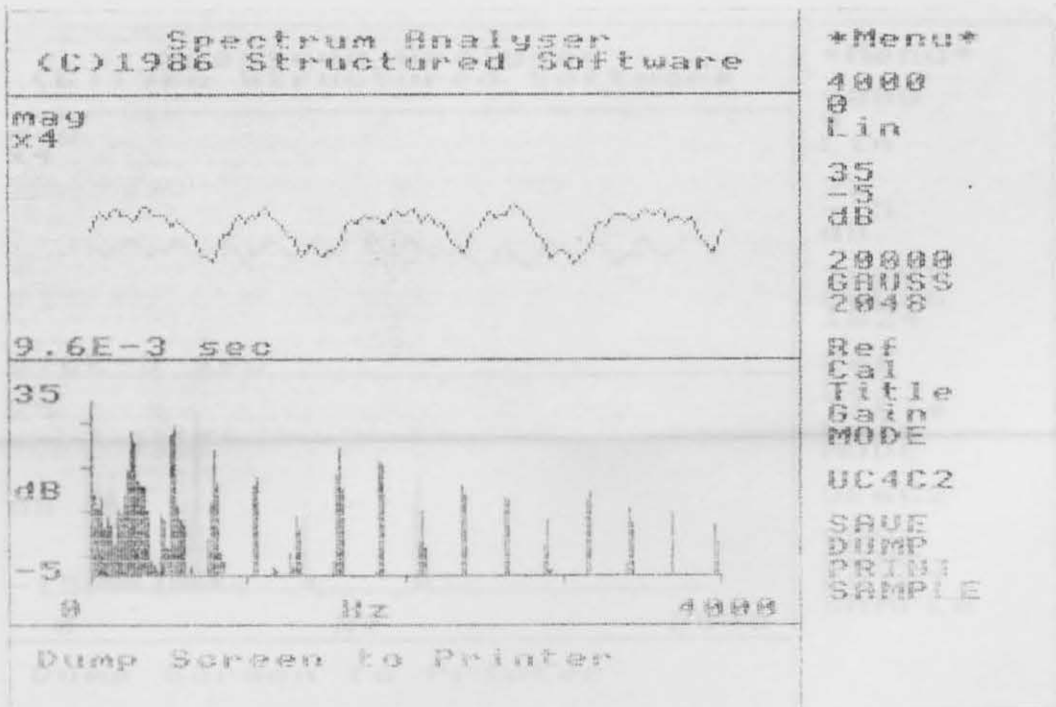



1784 C.G. Hubert (delay 0.2 sec.)

**Chart 5.2**
**The frequency spectra for the note c$^1$**

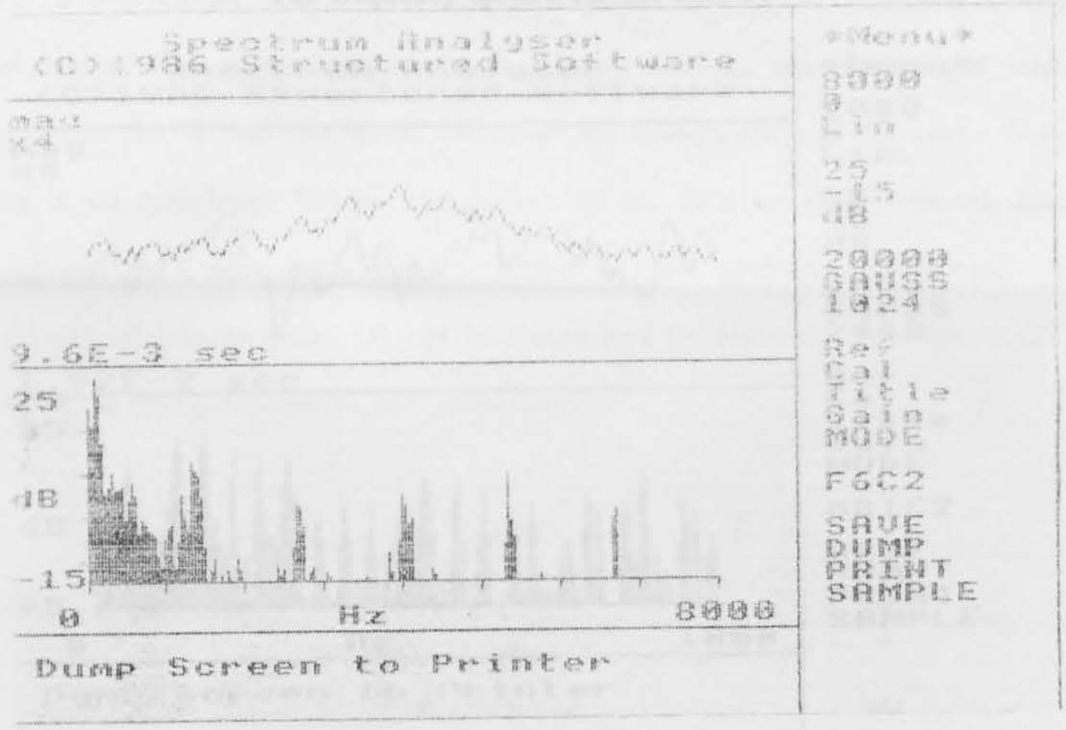



1763a J.A. Hass (delay 0.1 sec.)

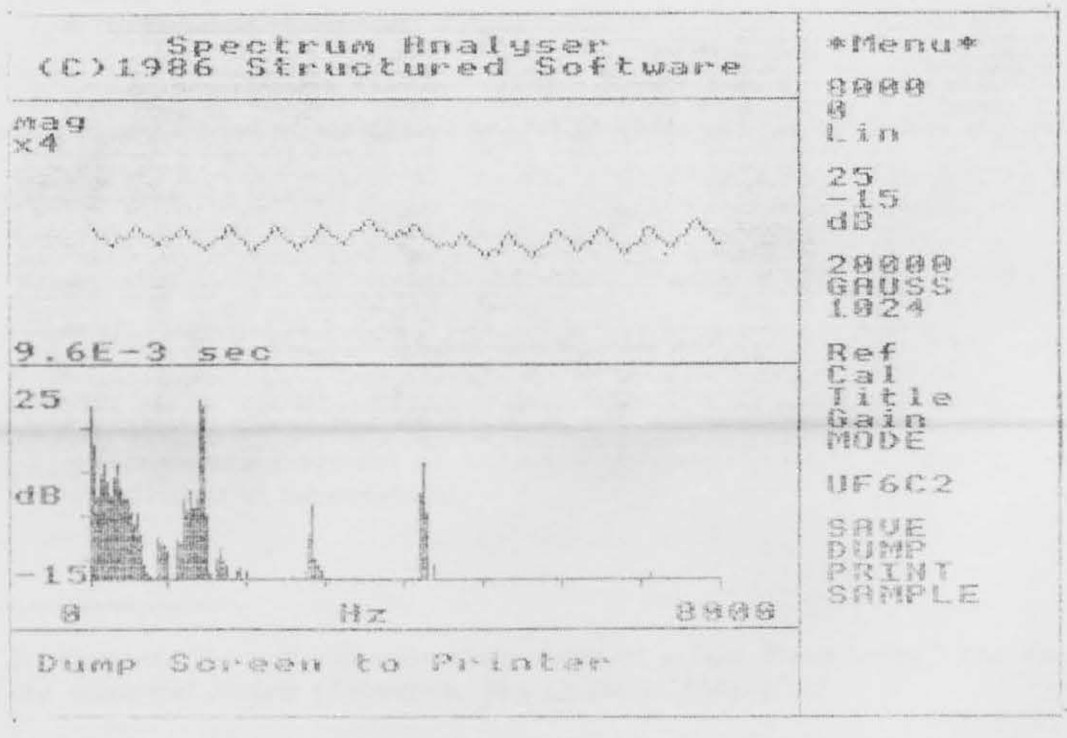



1784 C.G. Hubert (delay 0.1 sec.)

Chart 5.3
The frequency spectra for the note $f^3$



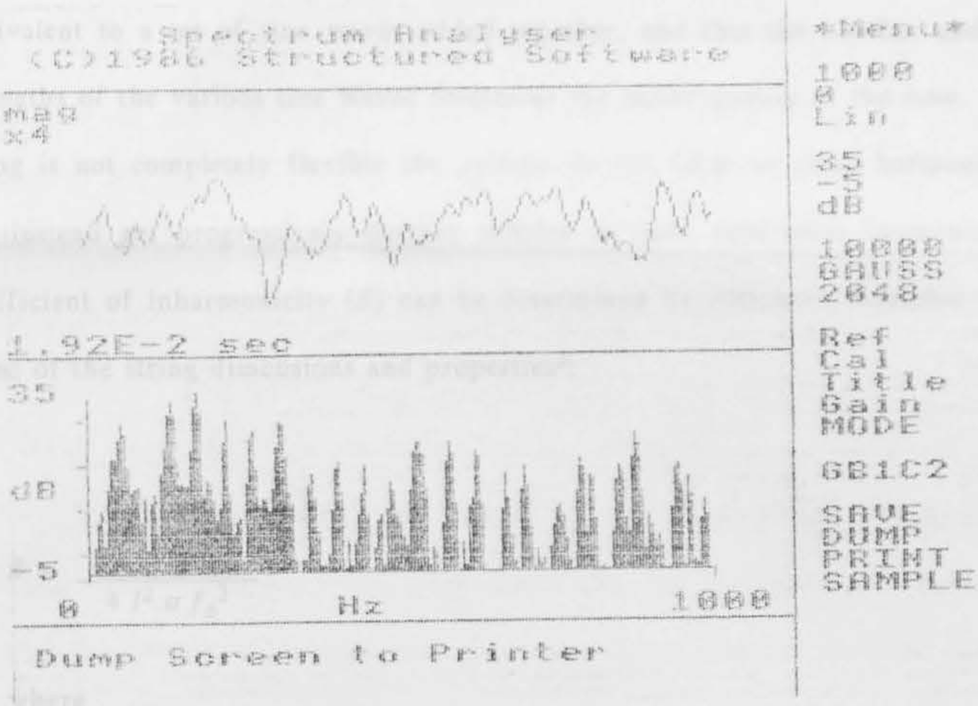

1763a J.A. Hass (delay 0.1 sec.)




1784 C.G. Hubert (delay 0.1 sec.)

Chart 5.4

**The frequency spectra for the note FF#**




1763a J.A. Hass (delay 0.2 sec.)

## THE ACOUSTICAL EFFECT OF THE OCTAVE STRINGS IN THE BASS

It is well known that musical soundwaves have a complex vibration, which is equivalent to a set of sine waves added together, and that the number and relative strengths of the various sine waves determine the sound quality of the note. Since a string is not completely flexible the partials do not form an exact harmonic series, but instead get progressively sharper relative to their equivalent harmonics. The coefficient of inharmonicity (*B*) can be determined by Fletcher's Equation No.27 in terms of the string dimensions and properties[2]:

$$B = \frac{\pi^2 Q S K^2}{4 l^2 \sigma f_o^2}$$

where
$B$ = coefficient of inharmonicity
$Q$ = Young's Modulus (stiffness coefficient)
$S$ = cross-sectional area
$K$ = radius of gyration (diameter ÷ 4)
$\sigma$ = linear density (mass per unit length)
$l$ = string length
$f_o$ = fundamental frequency

Using the coefficient of inharmonicity, the frequency of the $n^{th}$ partial ($f_n$) can be calculated using the formula:[3]

$$f_n = nf_0 \, (1+Bn^2)^{\frac{1}{2}}$$

where
$n$ = number of the partial
$f_o$ = fundamental frequency
$B$ = coefficient of inharmonicity

[2] H. Fletcher, "Normal Vibration Frequencies of a Stiff Piano String," *The Journal of the Acoustical Society of America*, 36:1 (January 1964), p.205.

[3] H. Fletcher, "Normal Vibration Frequencies of a Stiff Piano String," *The Journal of the Acoustical Society of America*, 36:1 (January 1964), p.204.

The harmonic structure of the bass notes is particularly complex because the sound in this part of the compass is produced by the vibrations of three strings: two 8ft strings of approximately the same length and a 4ft string more than half the length of the two 8ft strings. An insight into the effect of the 4ft strings on the timbre of the bass notes can be gained by comparing the frequency spectrum of all three strings struck simultaneously by the tangent, with the frequency spectra of each of the three strings plucked individually by a quill.

Again using the 1763a JH in the Russell Collection, the note B (the highest note to have a string of 4ft pitch) was sounded by normal key action and recorded using a Digital Audio Tape Recorder. The sound was then analysed by a computer which plotted the frequency spectrum (see chart 5.5), and determined both the fundamental frequency and the coefficient of inharmonicity. From this the computer was able to construct a table of the frequencies of all the significant partials up to about 8.4 kHz. In order to identify which of the partials belonged to the 8ft strings and which belonged to the 4ft string spectral analysis was also used to investigate the plucked sound of each of the three strings. In this case, the keylever for the note B was depressed such that the tangent was touching all three strings, and then each string in turn was plucked with a quill, the sound recorded and then analysed in the same way as above. It was found that every frequency component listed for the struck sound of all three strings could in fact be clearly identified as belonging to either the 8ft or the 4ft set of inharmonic partials. Although the two 8ft strings vary in length by 11mm, it was found that this was not enough to make a significant difference to their inharmonicity and a mathematical mean of the values for the two 8ft strings was used. The frequency values for the 8ft strings and the 4ft string is given in table 5.1. In chart 5.5 the 8ft partials are numbered in black ink and the 4ft partials are numbered in red ink.

**Chart 5.5**
**The frequency spectra for the note B of the 1763a JH**
(based on a fundamental frequency of 115.7Hz)

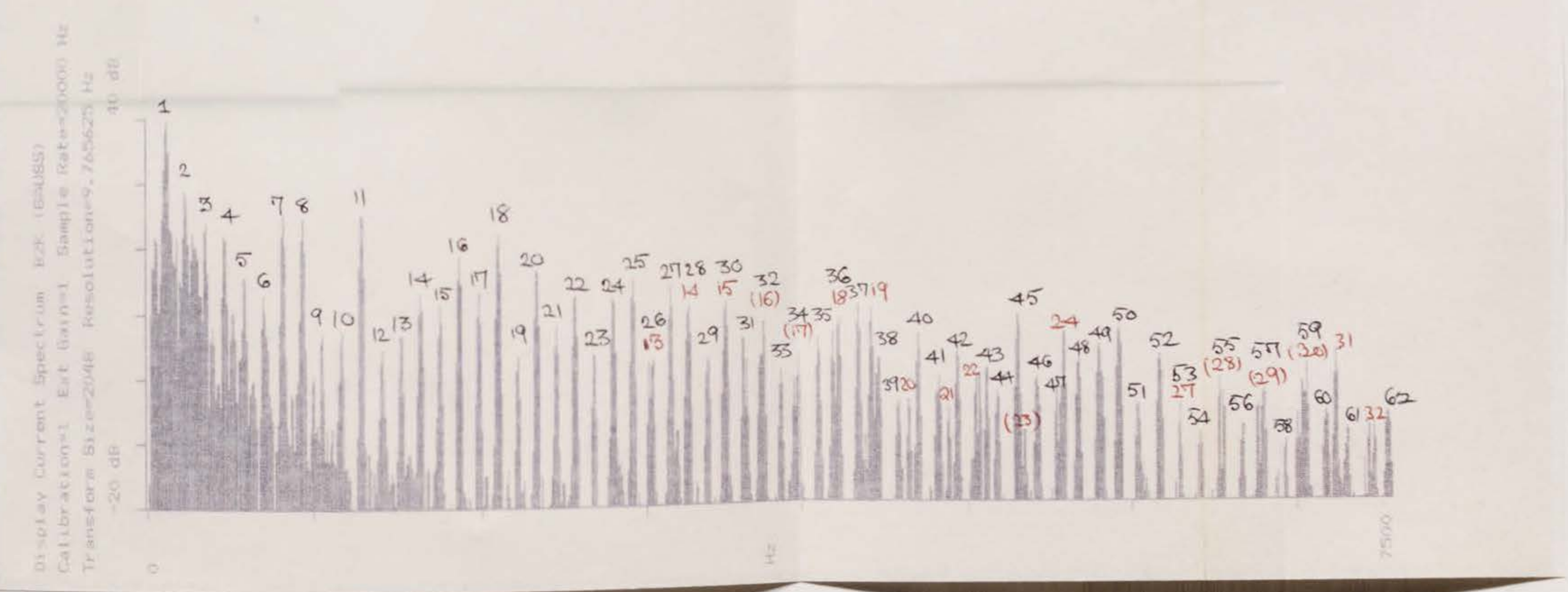


**Table 5.1 The Inharmonicity of the strings for the note B of the 1763a JH.**

| Mean 8ft | | 4ft | |
|---|---|---|---|
| Mode Number | Mode Frequency | Mode Number | Mode Frequency |
| 1 | 115.7 | | |
| **2** | **231.5** | **1** | **231.7** |
| 3 | 347.3 | | |
| **4** | **463.0** | **2** | **463.4** |
| 5 | 578.8 | | |
| **6** | **694.7** | **3** | **695.1** |
| 7 | 810.5 | | |
| **8** | **926.4** | **4** | **926.9** |
| 9 | 1042.4 | | |
| **10** | **1158.4** | **5** | **1158.6** |
| 11 | 1274.5 | | |
| **12** | **1390.6** | **6** | **1390.5** |
| 13 | 1506.9 | | |
| **14** | **1623.2** | **7** | **1622.3** |
| 15 | 1739.5 | | |
| 16 | 1856.0 | 8 | 1854.3 |
| 17 | 1972.6 | | |
| 18 | 2089.3 | 9 | 2086.3 |
| 19 | 2206.0 | | |
| 20 | 2322.9 | 10 | 2318.4 |
| 21 | 2440.0 | | |
| 22 | 2557.1 | 11 | 2550.6 |
| 23 | 2674.4 | | |
| 24 | 2791.8 | 12 | 2782.8 |
| 25 | 2909.4 | | |
| | | 13 | 3015.2 |
| 26 | 3027.1 | | |
| 27 | 3145.0 | | |
| 28 | 3263.0 | 14 | 3247.7 |
| 29 | 3381.2 | | |
| 30 | 3499.6 | 15 | 3480.3 |
| 31 | 3618.2 | | |
| | | 16 | 3713.1 |
| 32 | 3736.9 | | |
| 33 | 3855.9 | | |
| | | 17 | 3946.0 |
| 34 | 3975.0 | | |
| 35 | 4094.3 | | |
| | | 18 | 4179.0 |
| 36 | 4213.9 | | |
| 37 | 4333.7 | | |
| | | 19 | 4412.2 |
| 38 | 4453.7 | | |
| 39 | 4573.9 | | |
| | | 20 | 4645.6 |
| 40 | 4694.3 | | |
| 41 | 4815.0 | | |
| | | 21 | 4879.1 |

| Mean 8ft | | 4ft | |
|---|---|---|---|
| Mode Number | Mode Frequency | Mode Number | Mode Frequency |
| 42 | 4936.0 | | |
| 43 | 5057.2 | | |
| | | 22 | 5112.8 |
| 44 | 5178.6 | | |
| 45 | 5300.3 | | |
| | | 23 | 5347.7 |
| 46 | 5422.3 | | |
| 47 | 5544.5 | | |
| | | 24 | 5580.9 |
| 48 | 5667.0 | | |
| 49 | 5789.9 | | |
| | | 25 | 5815.2 |
| 50 | 5912.9 | | |
| 51 | 6036.3 | | |
| | | 26 | 6049.7 |
| 52 | 6160.0 | | |
| **53** | **6284.0** | **27** | **6284.5** |
| 54 | 6408.3 | | |
| | | 28 | 6519.5 |
| 55 | 6533.0 | | |
| 56 | 6657.9 | | |
| | | 29 | 6754.8 |
| 57 | 6783.2 | | |
| 58 | 6908.8 | | |
| | | 30 | 6990.3 |
| 59 | 7034.7 | | |
| 60 | 7161.0 | | |
| | | 31 | 7226.1 |
| 61 | 7287.7 | | |
| | | 32 | 7462.1 |
| 62 | 7414.7 | | |
| 63 | 7542.0 | | |
| 64 | 7669.7 | | |
| | | 33 | 7698.5 |
| 65 | 7797.8 | | |
| 66 | 7926.3 | | |
| | | 34 | 7935.1 |
| 67 | 8055.1 | | |
| **68** | **8184.3** | **35** | **8172.0** |
| 69 | 8313.9 | | |
| | | 36 | 8409.2 |

While one might have expected the role of the 4ft string to be mainly that of strengthening the even partials of the 8ft sound, in fact this is not significant. Whereas the strength of neighbouring partials can vary by 15 or 20dB, even if the three strings are of equal loudness a third string can only increase the volume by about 2dB. Since the 4ft string is more than half the length (625mm) of the two 8ft strings (near string is 1052mm, far string is 1041mm), however, it has a lower calculated inharmonicity ($1.27^{-5}$) than the two 8ft strings (mean value = $1.76^{-5}$). The different inharmonicity of the 4ft string means that it is adding a whole range of new components to the sound. For frequencies up to about 1.6 kHz the frequencies for both the 4ft and the 8ft sets of partials are both in phase and in step. By about 2.5 kHz the two sets are becoming more and more out of phase until by about 6.3 kHz the two sets are back in phase but one partial away from the theoretical, with the 27th partial of the 4ft matching the 53rd partial of the 8ft rather than that of the 54th partial. The two sets again start going out of phase until about 8.2 kHz when they again come back in phase, but now two partials away from the theoretical, with the 35th partial of the 4ft matching the 68th partial of the 8ft rather than the 70th partial.

# Chapter 6

## ANALYTICAL METHOD

### INTRODUCTION

One of the most striking areas of a clavichord built in the Hass workshops is the soundboard. The soundboard and bridges are beautifully made, and the positioning of the pins on the bridges and on the soundboard is very precise and regimented. The obvious care taken by Hieronymus and Johann Hass in the marking out of the position of the bridge pins on the bridges, and in the marking out of the position of the 8ft tuning pins and the 4ft hitchpins on the soundboard indicates that they gave special weight to this aspect of instrument building. Consequently, one of the principal aims of my research has been to try and determine the actual method employed by Hass to mark out his clavichords.

### THE DETERMINATION OF THE 8FT-BRIDGE SHAPE AND THE RACK-SLOT SPACING PATTERN

It has been shown in chapter 3, pp.64-6 that both members of the Hass family were aiming at certain nominal string-scaling values: 6 Zolle for the length of $c^3$, for example, 12 Zolle for the length of $c^2$, and 24 Zolle for the length of $c^1$. The treble string scalings of Hass clavichords are always close to these values, but since it is the lateral spacing of the strings and not the length of the strings which is important for the mechanical functioning of the instrument[1] small variations in the string scalings occur. Since the 8ft string scalings are determined partly by the shape and placing of the 8ft bridge, partly by the lateral spacing of the pins on the bridges,

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[1] G. O'Brien, *Ruckers, a harpsichord and virginal building tradition* (Cambridge: Cambridge University Press, 1990), pp.67-8, has found that the members of the Ruckers family "were primarily interested in the sound and action of their instruments and not in their static non-resonant parts."

and partly by the tangent positioning, it is necessary to analyse each of these variables in order to understand the origin of these small variations in the string scalings. Since the tangents of Hass clavichords are in a line with the centre of the tail of the keylever, which is in the centre of the rack slot, the spacing of the rack slots determines the tangent positions. I am calling the spacing of the rack slots the rack-slot spacing pattern.

The method adopted for analysing the 8ft bridge shape and for analysing the rack-slot spacing pattern of Hass clavichords was to make rubbings of them. Since the 8ft bridge pins are positioned equidistant from the edge of the bridge a rubbing of the tops of the 8ft bridge pins gives a very good impression of the overall shape of the 8ft bridge. The rubbings were made by positioning a small sheet of stable plastic drafting film over the 8ft bridge and then rubbing over the tops of the 8ft bridge pins with a type of wax crayon known as a cobbler's heelball. The rack-slot spacing pattern was recorded by temporarily attaching a strip of stable plastic drafting film about 40mm wide to the front edge of the rack, and then gently rubbing over the positions of the rack slots with a cobbler's heelball. It was then possible to make a comparison of the bridge shape and of the rack-slot spacing pattern of different instruments by superimposing one rubbing on top of another. The various rack-slot spacing patterns and 8ft bridge shapes employed by the Hass family, together with their effect on the string scalings of three C to $d^3$ clavichords has already been shown in previous chapters.

## THE DETERMINATION OF HASS'S METHOD OF MARKING OUT THE POSITION OF THE 8FT AND 4FT BRIDGE PINS

Since the treble strings are thinner and have a lower tension than the heavier bass strings they need to have a greater sidedraft angle at the bridge than the heavier bass strings to prevent them from being lifted off the bridge when a keylever is depressed. The strings are basically parallel to one another between the 8ft bridge pins and the 8ft tuning pins, so one of the ways to vary the sidedraft is by splaying out the strings. Hass achieves this by varying the lateral spacing of the strings. The bridge pins are positioned so that the finer treble 8ft strings are relatively close together, whereas in the bass the bridge pins are positioned so that the thicker strings are further apart and there is enough space for a 4ft string to be positioned between each pair of 8ft strings. It is these differences in the lateral spacing of the strings which partly explains variations in the string scalings of Hass clavichords. If the bridge pins are more widely spaced on one instrument than another, for example, each 8ft bridge pin will be progressively further down the bridge and the distance from the tangent to the pins in the bridge will be greater.

My starting point for the determination of Hass's method of marking out their clavichords was a hypothesis propounded by Grant O'Brien. O'Brien suggested to me that the position of both the bridge pins and the hitchpins may have been marked out with the soundboard removed from the instrument, and with the same calibrated stick held perpendicularly to the angle of the strings. The marking-out stick could be held at right-angles to the strings as it was moved across the instrument by positioning it against a wedge-shaped piece of wood, whose angle was the same as the proposed angle of the strings. Had this been the method used by Hass to mark out his clavichords, however, the strings would be parallel, and each 4ft string in the bass would be centrally positioned between its pair of 8ft strings. Since the strings aren't parallel and the bass 4ft strings are often badly positioned relative to their 8ft strings it was felt, therefore, that this was not the method adopted by Hass.

The procedure which led eventually to the discovery of Hass's true method of marking out is based on Grant O'Brien's string band strip method.[2] This involves marking the harpsichord bridge-pin positions on a strip of stable drafting film kept perpendicular to the spine of the instrument. O'Brien's procedure was, however, found to be inappropriate for Hass clavichords because the treble 8ft tuning pins are positioned between the 8ft bridge and the spine of the instrument and so interfere with the strip of drafting film. Consequently, the only way which could be used to record the position of the clavichord bridge pins relative to the spine was to measure each one individually. This was done by setting a ruler into a block of wood that was high enough to position the ruler above the tops of the tuning pins. The ruler was then fitted with a sliding attachment and pointer which was able to reach down to the upper surface of the bridge. Using the pointer to locate the centre of the pin, the distance from the spine was then read off the calibrations on the ruler.

**Plate 6.1**
**Measuring the position of the 8ft bridge pins from the spine**

[2] G. O'Brien, "The determination of the original compass and disposition of Ruckers harpsichords," *Colloquium: Ruckers klavecimbels en copieën* (Antwerp, 1977), pp.36-47.

Bridge-pin measurements for two standard Hass clavichords (the C to $d^3$ 1728 HH and the FF to $f^3$ 1743b HH) plus the unique FF to $f^3$ triple-strung 1761a JH are given at the end of this chapter in tables 6.1a, 6.2a and 6.3a respectively. These tables give the actual measurements in millimetres for each near pin of a pair of 8ft bridge pins from the spine, together with the measurement of each 4ft bridge pin from the spine.

Graphs 6.1 to 6.3 show plots of these bridge-pin measurements (together with plots of the measurements of the hitchpins and tuning pins drawn relative to the bottom 8ft bridge pin) with the origin moved from the spine to the position of the lowest note. This means that the plotted points show the variations in the lateral spacing of the pairs of 8ft strings and the variation in the lateral spacing of the 4ft strings. Changes in the lateral spacing of the pairs of 8ft bridge pins and the single 4ft bridge pins can be easily seen as a change in the slope of the line joining the plotted points. Each linear segment of a plot represents a section of bridge pins with the same lateral spacing. By dividing the total lateral spacing of each segment by the number of intervals between successive 4ft bridge pins and successive pairs of 8ft bridge pins (one octave of pins from FF to F has, for example, twelve intervals) the line segments express the lateral string spacing in millimetres. If the lateral spacing is converted from millimetres to Hamburg Zolle, by dividing the number of millimetres in each line segment by 23.874, the line segments express the lateral string spacing in units of the Hamburg Zoll. Tables 6.1b, 6.2b and 6.3b show the number of 8ft string pairs and single 4ft strings in each group of pins with the same lateral spacing, and the distance in Zolle occupied by them for the 1728 HH, the 1743b HH and the 1761a JH respectively. By converting the figures in these tables into the number of intervals in an integral number of Hamburg Zolle we can then find the likely divisions scribed on Hass's original marking-out stick. Tables 6.1c. 6.2c and 6.3c show the number of equally-spaced calibrations on the different marking-out sticks used by Hass for the same three clavichords in integral units of the Hamburg Zoll.[3]

It is important to stress that only when the pin positions are measured perpendicularly to the spine do the lateral spacing of the pins fall into groups in which there are an integral number of pins in an integral number of Hamburg Zolle. If the position of the bridge pins is not measured at right-angles to the spine the spacings work out as non-integral units of the Hamburg Zoll.

As an example of this procedure I will now examine the 8ft bridge pinning of the C to $d^3$ 1728 HH. Graph 6.1 includes a plot of the distance of the 8ft bridge pins from the spine of the 1728 HH, with the origin moved from the spine to the bottom note C. From this plot it is clear that the 8ft bridge pins are in three different spacing groups, and that the groupings of the pins with the same lateral spacing changes at the c's: C to $c^1$, $c^1$ to $c^2$ and $c^2$ to $d^3$. Since the total lateral spacing of each group diminishes from bass to treble (C to $c^1$ = 177mm, $c^1$ to $c^2$ = 47mm, and $c^2$ to $d^3$ = 36½mm) the three linear segments represent tighter string spacing in the treble than in the bass. Table 6.1b includes the total lateral spacing of each group of 8ft bridge pins converted into Hamburg Zolle, together with the number of intervals between successive pairs of 8ft bridge pins within each spacing group. The bottom twenty-one pairs of pins from C to $c^1$ (20 intervals) are positioned in 7½ Zolle, the eight pairs of pins from $c^1$ to $c^2$ (7 intervals) are positioned in 2 Zolle and the nine pairs of pins (8 intervals) from $c^2$ to $d^3$ are positioned in 1½ Zolle. Except perhaps for the spacing group from $c^1$ to $c^2$ these numbers seem at first to be incomprehensible. However, as table 6.1c shows, when these spacings are converted into the number of intervals in whole units of Hamburg measure they

[3] For the calculation of the bridge pin marking-out sticks of nine other Hass clavichords see appendix 1.

appear more logical. Twenty intervals in 7½ Zolle can, for instance, also be expressed as eight intervals in 3 Zolle, and eight intervals in 1½ Zolle can also be expressed as sixteen intervals in 3 Zolle. In other words the top octave of 8ft bridge pins are twice as tightly spaced as the bottom two octaves of bridge pins.

Having analysed the bridge pinning of almost all the surviving Hass clavichords I have found that the pairs of 8ft bridge pins of C to $d^3$ clavichords are in three different spacing groups, and that the 4ft bridge pins are in two different spacing groups. The three groupings of 8ft bridge pins with the same lateral spacing are: C to $c^1$, $c^1$ to $c^2$ and $c^2$ to $d^3$; and the two groupings of 4ft bridge pins with the same lateral spacing are: C to F and F to d. In contrast, the pairs of 8ft bridge pins of standard FF to $f^3$ clavichords are in four different spacing groups. There are, however, still only two different spacing groups of 4ft bridge pins. The four groupings of 8ft bridge pins are: FF to f, f to $f^1$, $f^1$ to $f^2$ and $f^2$ to $f^3$; and the two groupings of 4ft bridge pins are: FF to F and F to d (c or B).

Both the FF to $d^3$ 1732b HH and the GG to $d^3$ 1748 JH have the same number of spacing groups as the standard five-octave models. In the case of the 1748 JH, however, the groupings of pins with the same lateral spacing changes at the g's rather than at the f's. The four groupings of 8ft bridge pins of the 1748 JH are: GG to g, g to $g^1$, $g^1$ to $g^2$ and $g^2$ to $d^3$; and the two groupings of 4ft bridge pins are: GG to G and G to d. The 1761a JH, disposed with three 8ft courses from c upwards, also has four groupings of 8ft bridge pins but these change at a combination of the f's and the c's. The four groupings of the 8ft bridge pins are: FF to c, c to $c^1$, $c^1$ to $f^2$ and $f^2$ to $f^3$; and the two groupings of the 4ft bridge pins are: FF to F and F to B.

The 4ft bridge pins have to be in two spacing groups in the part of the compass where there is only one 8ft spacing group because the 4ft and 8ft bridges aren't parallel and don't have the same shape. Since the pins are marked out at right-angles to the spine there have to be at least two 4ft spacing groups to one 8ft spacing group in order to compensate for this feature. Even so the 4ft bridge pins are often badly positioned relative to their respective 8ft strings. Sometimes the 4ft bridge pins are even on the wrong sides of the 8ft strings rather than being centrally positioned. This slight error is unimportant, however, because of the close vicinity of the tangent to the very accurately positioned bass 8ft hitchpins and 4ft tuning pins at the opposite end of the strings.

This analysis of the bridge pinning shows that Hass was using calibrated sticks which he held perpendicular to the spine while he moved them across the sound-board. One stick marked the positions of the 4ft bridge pins, and the other marked the pairs of 8ft bridge pins. This explains why the 4ft bridge pins are not centrally placed at the right-hand end and confirms the theory that the positions of the bridge pins were not marked out perpendicular to the strings. Had the marking-out stick been perpendicular to the strings, the 4ft bridge pins would be centrally placed and have the same spacing pattern as the pairs of 8ft bridge pins. This analysis also indicates that Hass must have had a series of master sticks, each with a different calibration. Depending upon the compass and model he was making at the time, Hass chose either two, three or four of these master sticks from which to mark the calibrations on his bridge-pinning stick. Sometimes the same calibration that appears to have been marked on one stick is used in a different part of the compass on another.

Furthermore, this process of analysing the bridge pinning of Hass clavichords also gives us a tool for the authentification of the (1725) HH, which has lost its original date and signature. The 8ft and 4ft bridge pins of the (1725) HH have, for example, the same spacing groups as the 8ft and 4ft bridge pins of surviving signed Hieronymus Hass C to $d^3$ clavichords. Furthermore, the position of the 4ft bridge pins of the (1725) HH were marked with a stick which had the same calibrations as those used by Hass. The likelihood of a builder other than Hass marking out the 4ft bridge of this instrument is, therefore, very remote.

## THE DETERMINATION OF HASS'S METHOD OF MARKING OUT THE POSITION OF THE 8FT TUNING PINS AND THE 4FT HITCHPINS

The positions of the 8ft tuning pins and the 4ft hitchpins could have been marked out using either a template or a calibrated stick held, like the bridge-pinning stick, at right-angles to the spine. If a template was used it could have taken the form of either a pinboard, or a board with a series of perforations into which a bradawl could be inserted. The use of a template to mark out the positions of these pins can be excluded as a possibility, however, since there are scribed lines for the 8ft tuning pins and a single scribed line for the 4ft hitchpins. It is most likely that Hieronymus and Johann Hass used the diagonally-scribed lines in conjunction with a calibrated stick. The scribed lines were used to determine the longitudinal position of the pins, and the calibrated stick (held perpendicularly to the spine) was used to determine the latitudinal position of the pins.

The same analytical method as described above for the 8ft and 4ft bridge pins was used to analyse the positions of the 8ft tuning pins and the 4ft hitchpins of the 1728 HH, the 1743b HH and the 1761a JH. Tables 6.1a, 6.2a and 6.3a include the distance of each 4ft hitchpin from the spine, and the distance of each near pin of a pair of 8ft tuning pins from the spine on the perpendicular section of the wrestplank and each near pin of a group of four 8ft tuning pins on the diagonal section of the wrestplank. These measurements are plotted in graphs 6.1 to 6.3 to show the various spacing groups. The lateral spacing of each group of pins with the same interval in Hamburg Zolle, together with the number of intervals between each 4ft hitch-pin, and near pin of a pair of 8ft tuning pins or near pin of a group of four 8ft tuning pins in that spacing group is given in tables 6.1b, 6.2b and 6.3b. What I believe to be the actual calibrations on Hass's marking-out sticks are given in tables 6.1c, 6.2c and 6.3c. Analyses of the 8ft tuning pins and 4ft hitchpins of other Hass clavichords can be found in Appendix 2.

The practice of the Hass family was to mark the position of the 4ft hitchpins onto the soundboard of their C to $d^3$ clavichords with the same stick which marked out the position of the bridge pins on the 4ft bridge. In the case of the (1725) HH and the 1728 HH the 4ft bridge pins and 4ft hitchpins are positioned an equidistance from the spine, such that the strings between the two sets of pins are parallel to the spine. In the case of the 1740b HH and the 1761b, however, the 4ft bridge- and hitch-pinning stick was positioned about $^1/_6$ Zoll nearer the soundboard front when marking out the position of the hitchpins, than when marking out the position of the bridge pins. This means that the amount of sidedraft of the later instruments is less than that of the earlier instruments.

Hieronymus and Johann Hass were clearly very concerned with the sidedraft of the FF to $f^3$ models, for they used three slightly different methods to mark out the position of the 4ft hitchpins of the five-octave models. The 4ft hitchpins of both the 1742a HH and the 1744a HH were marked out with the same stick which marked out the 4ft bridge pins, but with the stick positioned slightly nearer the soundboard front. This same method was also used by Johann Hass for the GG to $d^3$ 1748 JH.[4] Hitchpins for the 4ft strings of the 1743b HH were marked out with a completely different stick to that used for the 4ft bridge pins, whilst the 4ft hitchpins of all

[4] See appendix 2.

standard Johann Hass five-octave FF to $f^3$ models were marked out using a modified 4ft bridge-pinning stick. The groupings of 4ft hitchpins with the same lateral spacing of the 1763a JH, for example, changes at the same note (F) as the 4ft bridge pins. Furthermore, the actual lateral spacing of the bottom octave of 4ft bridge pins and 4ft hitchpins is the same. From F to B, however, the lateral spacing of the 4ft hitchpins is greater than the lateral spacing of the bridge pins. As a consequence of this the sidedraft of the strings behind the 4ft bridge pins for the 1763a JH is slightly greater at the top note (B = 4.08°) than at the bottom note (FF = 4.06°).

The position of the 8ft tuning pins of the C to $d^3$ models, which are in two rows throughout, was marked onto the soundboard with sticks very similar to those used for marking the position of the 8ft pins on the 8ft bridge. As with the 8ft bridge pins, the 8ft tuning pins are in three different spacing groups, C to $c^1$, $c^1$ to $c^2$ and $c^2$ to $d^3$. Also, the interval between each successive pair of 8ft tuning pins is narrower in the treble than it is in the bass. The lateral spacing and positioning of the 8ft tuning pins of the (1725) HH is exactly the same as that of the 8ft bridge pins between the notes $c^1$ and $d^3$. From C to $c^1$, however, the lateral spacing of the 8ft tuning pins is greater than that of the bridge pins in order to reduce the amount of sidedraft in the bass. In contrast, the lateral spacing of the 8ft bridge pins and 8ft tuning pins of both the 1740b HH and the 1761b JH C to $d^3$ clavichords is the same from the note C to the note $c^2$. From $c^2$ to $d^3$, however, the lateral spacing of the 8ft tuning pins of both these instruments is greater than the 8ft bridge pins to increase the amount of sidedraft in the treble.

Tuning pins for the 8ft strings of five-octave FF to $f^3$ clavichords are usually positioned in four rows, except for the bottom three pairs of pins (FF to GG) which usually stand in two rows.[5] The bottom three pairs of 8ft tuning pins stand in two rows to enable the soundboard to vibrate more freely at the bass end of the 8ft bridge. Along the diagonal section of the wrestplank the tuning pins are arranged in units of four. The actual number of pins positioned in the two sections of the 8ft wrestplank varies. The tuning pins for all but one Hieronymus Hass five-octave clavichord, the 1744a HH, are arranged with FF to c# positioned perpendicularly to the spine, and with d to $f^3$ positioned diagonally to the spine. In the case of the 1744a HH the two sections of tuning pins are FF to A and $B^b$ to $f^3$. Except for the 1747 JH and the 1755 JH, the tuning pins of Johann Hass five-octave clavichords are arranged in the same manner as those of the 1744a HH. Both the 1747 JH and the 1755 JH differ from the usual layout in that the pins for the notes FF to B are positioned pependicularly to the spine rather than FF to A, and the pins for the notes c to $f^3$ are positioned diagonally to the spine rather than $B^b$ to $f^3$.

The bottom seven pairs of tuning pins (FF to BB) of all Johann Hass five-octave clavichords are set forward towards the soundboard front and away from the rest of the pins by about 1 to 1½ Zolle. This is in order to reduce the sidedraft of the bass strings.

In most cases there are three 8ft tuning-pin spacing groups: two spacing groups for the pairs of pins positioned in lines parallel to the right-hand case end, and one spacing group for the units of four pins positioned in lines diagonal to the right-hand case end. This means that there are two tuning-pin spacing groups to one 8ft bridge-pin spacing group in the bass, and one tuning-pin spacing group to three bridge-pin spacing groups in the treble. The bottom twelve pairs of tuning pins for the notes FF to E (11 intervals) of the 1742a HH are, for example, equidistant in $3^5/_{24}$ Zolle or $^7/_{24}$ Zoll apart, from F to c# the nine pairs (8 intervals) are equidis-

[5] Exceptionally, the 8ft tuning pins at the right-hand end of the soundboard of both the 1742a HH and the 1742b HH stand in four rows throughout.

tant in $2^2/_7$ Zolle or $^2/_7$ Zoll apart, and from d to $f^3$ the twenty units of four pins are ½ Zoll apart. Unusually, the tuning pins of the 1743b HH are in four different spacing groups: FF to BB, C to c#, d to $e^1$ and $e^1$ to $f^3$. The 8ft tuning pins of most standard FF to $f^3$ models of Johann Hass are in three different spacing groups: FF to BB, C to A and $B^b$ to $f^3$. From FF to BB the seven pairs of pins (6 intervals) are positioned in 2 Zolle, there is then a space of 1½ Zolle and the ten pairs of pins (9 intervals) for the notes C to A are equally-spaced in 3 Zolle. Along the diagonal wrestplank the twenty-two groups of four pins (21 intervals) are positioned ½ Zoll apart.

The tuning-pin arrangement of the triple-strung 1761a JH is very interesting. For the range of the 4ft strings (FF to B) the bottom nineteen pairs of 8ft tuning pins are positioned $^1/_3$ Zoll apart, with the bottom seven pairs set forward towards the right-hand case front as normal. For the range of the triple 8ft stringing, however, the tuning pins are grouped in threes. Each of the twenty-seven groups of three 8ft tuning pins on the diagonal section of the wrestplank (from c to $f^3$) is, like the pairs of tuning pins, $^1/_3$ Zoll apart.

### THE DETERMINATION OF HASS'S METHOD OF MARKING OUT THE POSITION OF THE BASS 8FT HITCHPINS AND THE 4FT TUNING PINS

The bass 8ft hitchpins of C to $d^3$ models (for the notes C to $e^b$/e or C to e) form two rows $^2/_3$ Zoll apart, which are perpendicular to the spine. One row is for the long strings and one row is for the short strings. The pairs of bass 8ft hitchpins of FF to $f^3$ models (for the notes FF to e) form four rows perpendicular to the spine. Tuning pins for the 4ft strings of all models are positioned in two rows ¼ Zoll apart in the central space between the rows of bass 8ft hitchpins. The interval between each 4ft tuning pin and each successive pair of 8ft hitchpins must be the same because the 4ft tuning pin locates the 4ft string centrally between the corresponding pair of 8ft strings. Consequently, the positions of the 4ft tuning pins and bass 8ft hitchpins were marked onto the 4ft wrestplank/bass 8ft hitchpin rail using the same stick. It is clearly shown in the tables 6.1a-c, 6.2a-c and 6.3a-c, in the graphs 6.1 to 6.3, and in appendix 3 that the bass 8ft hitchpins have precisely the same lateral spacing as the 4ft tuning pins.

The bass 8ft hitchpins and 4ft tuning pins of C to $d^3$ clavichords are in a single spacing group. However, the interval between successive pairs of pins on the C to $d^3$ clavichords of Hieronymus Hass is different from that on the clavichords of Johann Hass. The sixteen pairs of bass 8ft hitchpins and fifteen 4ft tuning pins of the (1725) HH, the 1728 HH and the 1740b HH were all marked out with a stick with the same calibration, although not necessarily the same stick. The score marks on the marking-out stick (7 calibrations in 2 Zolle) of these three instruments was determined by fitting the fifteen 4ft tuning pins (14 intervals) into 4 Zolle, and then extending this spacing pattern for the sixteenth pair ($e^b$-e) of bass 8ft hitchpins. In contrast to these instruments, the seventeen pairs of 8ft hitchpins and fifteen 4ft tuning pins of the C to $d^3$ 1746 JH and the C to $d^3$ 1761b JH are simply $\frac{1}{4}$ Zoll apart.

All Hieronymus Hass five-octave FF to $f^3$ clavichords were marked out with the same bass 8ft hitchpin and 4ft tuning pin stick, which had two spacing groups. In this case the marking-out stick was determined by spacing the bottom thirteen 4ft tuning pins FF to F (twelve intervals) into 3 Zolle, and the top ten 4ft tuning pins (nine intervals) into 2 Zolle. This latter spacing was just extended for the twenty-third and twenty-fourth pair of 8ft hitchpins. The same spacing patterns, 4 in 1 and 9 in 2 were used for the FF to $d^3$ 1732b HH, but the compass of each pattern is different, namely FF to C and C to d. The bottom octave of 4ft tuning pins and 8ft hitchpins of standard Johann Hass five-octave clavichords are spaced in $3^1/_3$ Zolle and the top ten (eight or seven) 4ft tuning pins are spaced $\frac{1}{4}$ Zoll apart. This same lateral spacing is used for the GG to $d^3$ 1748 JH but with the spacing groups based on the g's rather than the f's. Since there are the same number of bass 8ft hitchpins along the left-hand case end as standard models, the top 8ft note on the bass 8ft hitchpin rail of the GG to $d^3$ 1748 JH is $f^{\#}$ rather than e. This means, therefore, that the positions of the 4ft tuning pins and the bass 8ft hitchpins of the 1748 JH were probably marked out with a standard five-octave FF to $f^3$ stick.

**THE DETERMINATION OF HASS'S METHOD OF MARKING OUT THE POSITION OF THE TENOR, ALTO AND TREBLE 8FT HITCHPINS**

The treble, alto and tenor 8ft hitchpins (for the notes f to $d^3$) of all Hass C to $d^3$ clavichords stand in a single diagonal line on top of the rack. My initial attempt to determine Hass's method of marking out the pins on the top of the rack floundered, because I assumed that Hass was using a stick held at right-angles to the spine. It now appears unlikely that the 8ft hitchpins on top of the rack were marked out with a calibrated stick held at right-angles to the spine, since the lateral spacing between the top and bottom pins is usually only 1 Zoll. As the line of hitchpins is parallel to the front edge of the rack it is more logical to assume that they were positioned with a stick held up against the front edge of the rack. Consequently, the calibrations on the marking-out stick determined not the latidudinal position of the hitchpins relative to the spine, but rather the longitudinal position relative to the left-hand case end. The lateral spacing of the pins was determined simply by the angle of the rack. The normal procedure for measuring the position of the pins was, therefore, considered inappropriate. Unlike the other sets of pins, I have attempted to determine Hass's method of marking out the position of the tenor, alto and treble hitchpins by measuring the distance of each pin from the left-hand case end with a tape measure.

Exactly how Hass determined the spacing groups of these pins is still open to question, but I believe that in most cases it was done by projection. I have found, for instance, that the nineteen pairs of pins (37 intervals) of the (1725) HH are positioned in 24 Zolle, which means that the interval of each pin does not work out as a simple subdivision of the Zoll. The longitudinal spacing must, therefore, have been determined by projection. The longitudinal spacing of the hitchpins of the 1761b JH is, however, slightly easier to understand since there are twenty pairs in $24^3/_8$ Zolle. This makes each pin $^5/_8$ Zoll apart from its neighbour.

Although all other C to $d^3$ clavichords have twenty pairs of pins along the top of the rack and not nineteen, the 8ft hitchpin measurements of the (1725) HH are one of the clearest indications that this instrument is by Hieronymus Hass. The measurements of the 8ft hitchpins of the (1725) HH and the 1740b HH show such remarkable correlation, that Hass must have marked out the position of the pins on both clavichords.[6] The (1725) HH can thus be authenticated as a clavichord built in the workshop of Hieronymus Hass.

The hitchpins of standard FF to $f^3$ clavichords for the thirty-seven notes f to $f^3$ form two rows along the top of the rack, with thirty-seven pins in each row. As with the C to $d^3$ models the spacing of these pins is difficult to analyse. The thirty-seven pins (36 intervals) of each row of the 1755 JH are, for example, positioned in 31 Zolle; and the thirty-seven pins in each row of the standard FF to $f^3$ models of the 1760's are positioned in just under $30\frac{1}{2}$ Zolle. It may be that the longitudinal spacing of the hitchpins in the latter instance was determined by dividing 11 Zolle into 13 spaces, in which case the entire space occupied by the pins should be $30^6/_{11}$ Zolle and not $30\frac{1}{2}$ Zolle.

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6 See appendix 4.

**CONCLUSION**

It was the practice of the Hass family to use calibrated sticks to mark out both sets of bridge pins, the 4ft hitchpins and the 8ft tuning pins. These sticks were held perpendicular to the spine while they were moved across the soundboard area. The single stick used to mark out both the 4ft tuning pins and the bass 8ft hitchpins was also held perpendicular to the spine of the instrument, but the stick for the tenor, alto and treble 8ft hitchpins was held up against the front edge of the rack. This analysis of the marking-out sticks has helped us to understand the working methods of both Hieronymus and Johann Hass, and to enter into their minds as they evolved their designs, in a way that has been impossible hitherto for any maker. I strongly suspect that clavichord builders throughout Europe used these same methods to mark out their clavichords as well. The significance of this research for our deeper understanding of other Hamburg, Brunswick and Scandinavian builders is discussed in chapter 8.

**Table 6.1a**
**Distance of the pins from the spine of the 1728 HH**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $d^3$ | 47½ | 39 | 603 | | | | |
| $c^3$-$c^{\#3}$ | 52½ | 45 | 580½ | | | | |
| $b^{b2}$-$b^2$ | 57½ | 51 | 554½ | | | | |
| $a^2$ | 62½ | 56 | 529 | | | | |
| $g^2$-$g^{\#2}$ | 68 | 62 | 501 | | | | |
| $f^2$-$f^{\#2}$ | 72 | 68 | 471 | | | | |
| $e^{b2}$-$e^2$ | 76 | 73 | 439½ | | | | |
| $d^2$ | 80 | 79 | 408 | | | | |
| $c^2$-$c^{\#2}$ | 84 | 86½ | 377 | | | | |
| $b^{b1}$-$b^1$ | 88½ | 93 | 346 | | | | |
| $a^1$ | 93½ | 100 | 316 | | | | |
| $g^1$-$g^{\#1}$ | 100 | 108 | 284½ | | | | |
| $f^1$-$f^{\#1}$ | 108 | 114 | 254 | | | | |
| $e^{b1}$-$e^1$ | 115½ | 121 | 223 | | | | |
| $d^1$ | 123 | 128 | 191½ | | | | |
| $c^1$-$c^{\#1}$ | 131 | 138 | 161 | | | | |
| $b^b$-b | 138½ | 147 | 130 | | | | |
| a | 147 | 155 | 99 | | | | |
| g-g# | 156½ | 164 | 68 | | | | |
| f-f# | 165 | 172½ | 32 | | | | |
| $e^b$-e | 174 | 181 | | 31 | | | |
| d | 183½ | 188½ | | 37½ | 34 | 140 | 139 |
| c# | 192 | 197 | | 45 | 41½ | 147 | 147 |
| c | 201 | 206½ | | 51 | 47½ | 154 | 154 |
| B | 210 | 215 | | 57½ | 54½ | 161 | 164 |
| $B^b$ | 219 | 224 | | 64 | 60 | 170 | 174 |
| A | 227½ | 232 | | 71 | 67½ | 178 | 182½ |
| G# | 236 | 242 | | 77½ | 74 | 188 | 191½ |
| G | 245½ | 252 | | 84½ | 81 | 196 | 201 |
| F# | 254½ | 260½ | | 91 | 87½ | 204½ | 210½ |
| F | 263½ | 269½ | | 97½ | 94½ | 214 | 220 |
| E | 271½ | 277½ | | 104½ | 100½ | 223 | 227 |
| $E^b$ | 282½ | 287 | | 111 | 108 | 233 | 235 |
| D | 291½ | 295½ | | 118 | 114 | 242 | 244½ |
| C# | 299 | 304 | | 124½ | 121½ | 251½ | 254 |
| C | 308 | 314 | | 131½ | 127 | 261½ | 261 |

**Graph 6.1**
**Bridge pin, hitchpin and tuning pin positions of the 1728 HH**

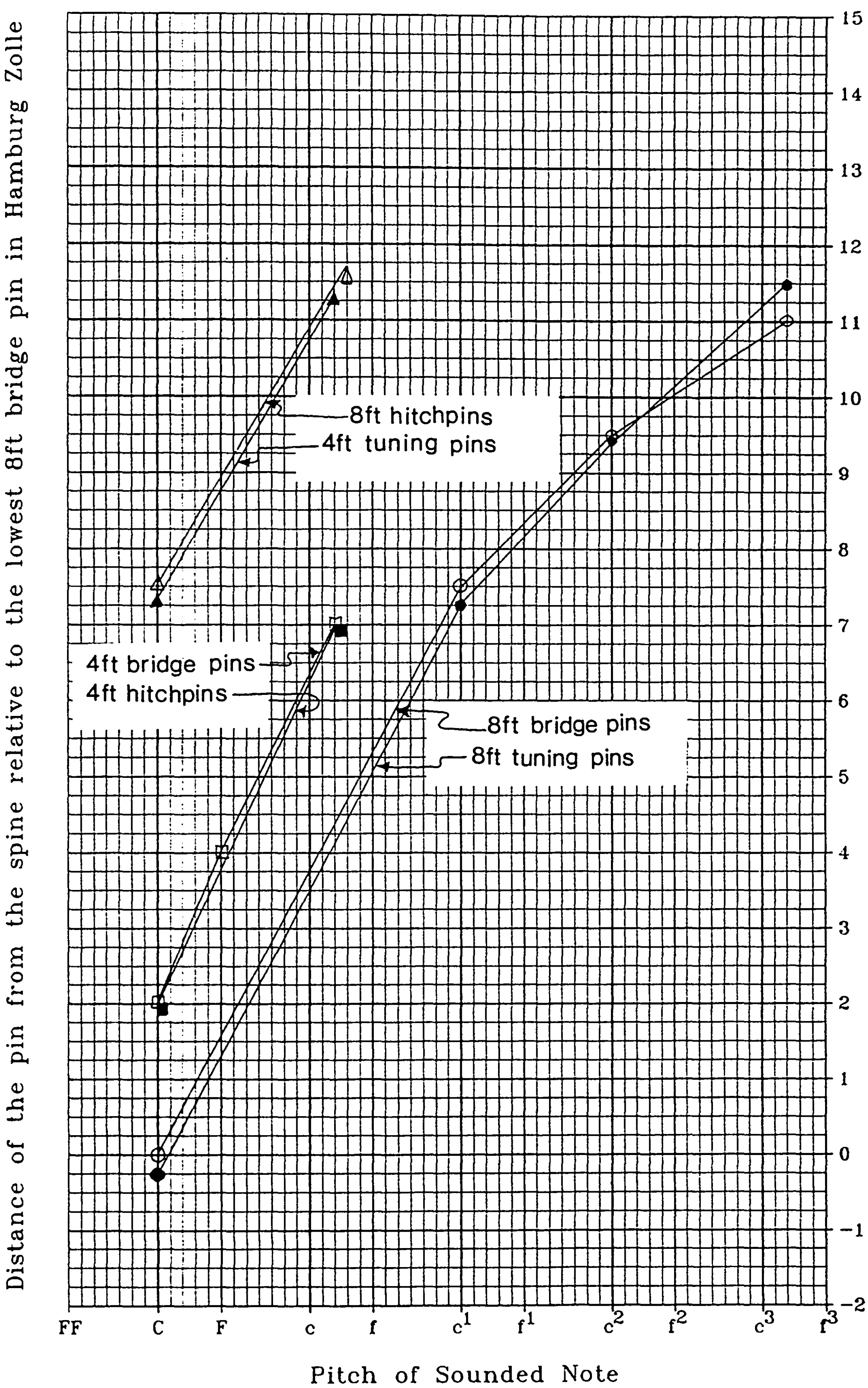


**Table 6.1b**
**Number of string pairs per Zoll for the 1728 HH**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 8FT BRIDGE PINS | 8FT TUNING PINS | 8FT TREBLE HITCHPINS | 8FT BASS HITCHPINS | 4FT TUNING PINS | 4FT BRIDGE PINS | 4FT HITCH PINS |
|---|---|---|---|---|---|---|---|
| $d^3$ | 8 in 1½ | 8 in 2 | 39 in 24 3/8 | | | | |
| $c^3$-$c^{\#3}$ | | | | | | | |
| $b^{b2}$-$b^2$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^2$-$g^{\#2}$ | | | | | | | |
| $f^2$-$f^{\#2}$ | | | | | | | |
| $e^{b2}$-$e^2$ | | | | | | | |
| $d^2$ | 8 in 1½ | 8 in 2 | | | | | |
| $c^2$-$c^{\#2}$ | 7 in 2 | 7 in 2 3/16 | | | | | |
| $b^{b1}$-$b^1$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^1$-$g^{\#1}$ | | | | | | | |
| $f^1$-$f^{\#1}$ | | | | | | | |
| $e^{b1}$-$e^1$ | | | | | | | |
| $d^1$ | 7 in 2 | 7 in 2 3/16 | | | | | |
| $c^1$-$c^{\#1}$ | 20 in 7½ | 20 in 7½ | | | | | |
| $b^b$-$b$ | | | | | | | |
| a | | | | | | | |
| g-g# | | | | | | | |
| f-f# | | | 39 in 24 3/8 | | | | |
| $e^b$-e | | | | 15 in 4 2/7 | | | |
| d | | | | | 14 in 4 | 9 in 3 | 14 in 5 |
| c# | | | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| G# | | | | | | | |
| G | | | | | | | |
| F# | | | | | | 9 in 3 | |
| F | | | | | | 5 in 2 | |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| C# | | | | | | | |
| C | 20 in 7½ | 20 in 7½ | | 15 in 4 2/7 | 14 in 4 | 5 in 2 | 14 in 5 |

**Table 6.1c**
**Marking-out stick divisions for the 1728 HH**

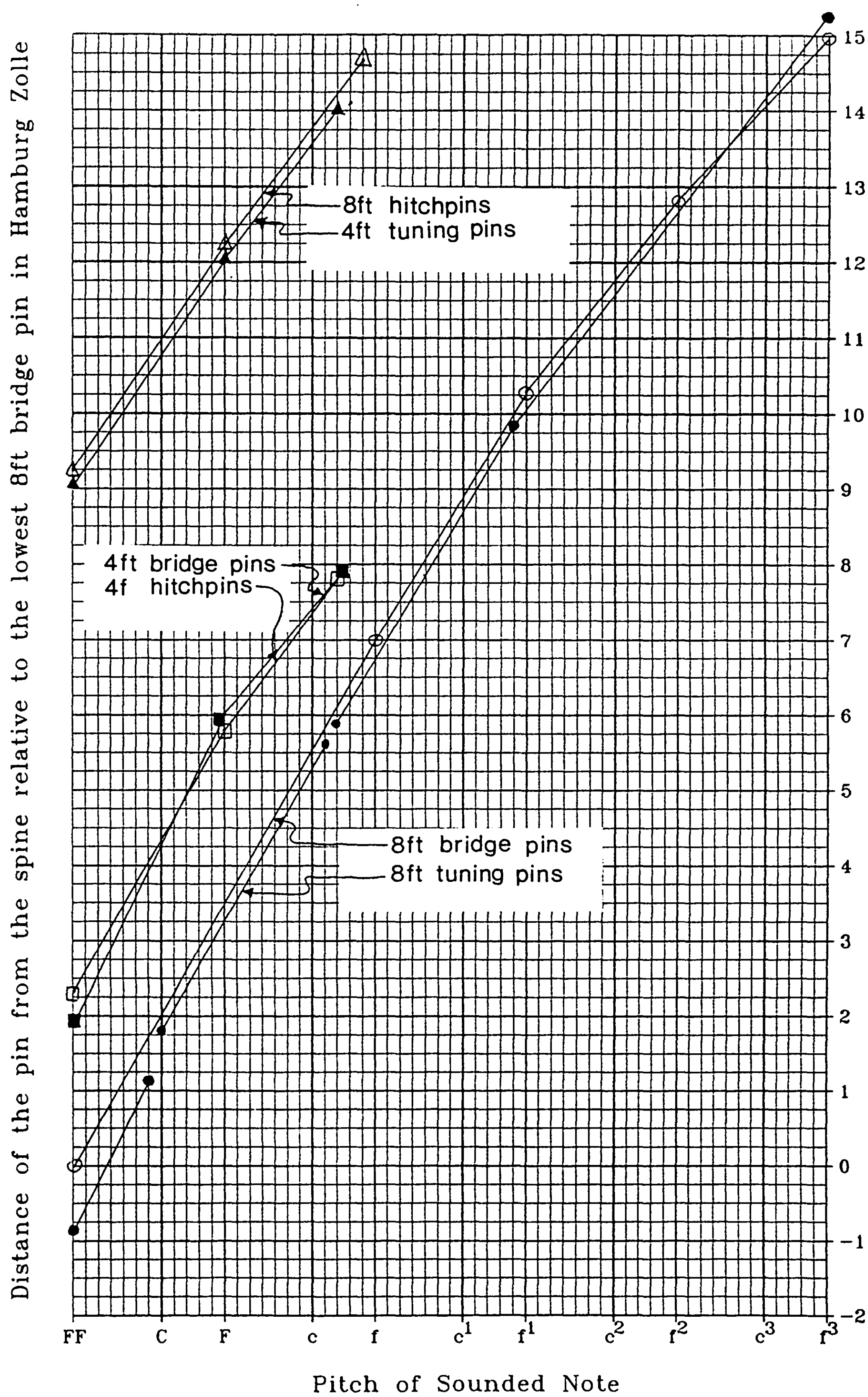
**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 8FT BRIDGE PINS | 8FT TUNING PINS | 8FT TREBLE HITCHPINS | 8FT BASS HITCHPINS | 4FT TUNING PINS | 4FT BRIDGE PINS | 4FT HITCH PINS |
|---|---|---|---|---|---|---|---|
| $d^3$ | 16 in 3 | 4 in 1 | 8 in 5 | | | | |
| $c^3$-$c^{\#3}$ | | | | | | | |
| $b^{b2}$-$b^2$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^2$-$g^{\#2}$ | | | | | | | |
| $f^2$-$f^{\#2}$ | | | | | | | |
| $e^{b2}$-$e^2$ | | | | | | | |
| $d^2$ | 16 in 3 | 4 in 1 | | | | | |
| $c^2$-$c^{\#2}$ | 7 in 2 | 16 in 5 | | | | | |
| $b^{b1}$-$b^1$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^1$-$g^{\#1}$ | | | | | | | |
| $f^1$-$f^{\#1}$ | | | | | | | |
| $e^{b1}$-$e^1$ | | | | | | | |
| $d^1$ | 7 in 2 | 16 in 5 | | | | | |
| $c^1$-$c^{\#1}$ | 8 in 3 | 8 in 3 | | | | | |
| $b^b$-b | | | | | | | |
| a | | | | | | | |
| g-$g^\#$ | | | | | | | |
| f-$f^\#$ | | | 8 in5 | | | | |
| $e^b$-e | | | | 7 in 2 | | | |
| d | | | | | 7 in 2 | 3 in 1 | 14 in 5 |
| $c^\#$ | | | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | | | 3 in 1 | |
| F | | | | | | 5 in 2 | |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | | | | |
| C | 8 in 3 | 8 in 3 | | 7 in 2 | 7 in 2 | 5 in 2 | 14 in 5 |

**Table 6.2a**
**Distance of the pins from the spine of the 1743b HH**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 34 | | 774½ | | | | |
| $e^3$ | 37 | 37 | 754 | | | | |
| $e^{b3}$ | 41 | | 734 | | | | |
| $d^3$ | 45 | 46 | 714½ | | | | |
| $c^{\#3}$ | 49 | | 693½ | | | | |
| $c^3$ | 54 | 57 | 674 | | | | |
| $b^2$ | 58 | | 654 | | | | |
| $b^{b2}$ | 63 | 67 | 634 | | | | |
| $a^2$ | 68 | | 614 | | | | |
| $g^{\#2}$ | 72 | 76 | 594 | | | | |
| $g^2$ | 77 | | 574 | | | | |
| $f^{\#2}$ | 82 | 88 | 553½ | | | | |
| $f^2$ | 87 | | 533½ | | | | |
| $e^2$ | 92 | 98 | 513½ | | | | |
| $e^{b2}$ | 96 | | 493 | | | | |
| $d^2$ | 101 | 109 | 473 | | | | |
| $c^{\#2}$ | 106 | | 453 | | | | |
| $c^2$ | 111 | 118 | 432 | | | | |
| $b^1$ | 116 | | 412 | | | | |
| $b^{b1}$ | 121 | 131 | 392 | | | | |
| $a^1$ | 126 | | 372 | | | | |
| $g^{\#1}$ | 131 | 141 | 352 | | | | |
| $g^1$ | 136½ | | 331½ | | | | |
| $f^{\#1}$ | 142 | 152 | 311½ | | | | |
| $f^1$ | 147 | | 291½ | | | | |
| $e^1$ | 153 | 163 | 271½ | | | | |
| $e^{b1}$ | 160 | | 251 | | | | |
| $d^1$ | 166 | 175 | 231 | | | | |
| $c^{\#1}$ | 173 | | 210½ | | | | |
| $c^1$ | 179 | 189 | 191 | | | | |
| b | 185½ | | 170½ | | | | |
| $b^b$ | 193 | 201 | 150½ | | | | |
| a | 200 | | 130 | | | | |
| $g^\#$ | 207½ | 216 | 110 | | | | |
| g | 214 | | 90½ | | | | |
| $f^\#$ | 222 | 231 | 69½ | | | | |
| f | 229 | | 50 | | | | |
| e | 237 | 245 | | 48 | | | |
| $e^b$ | 244 | | | 53½ | | | |
| d | 252 | 259 | | 58½ | 57 | 198½ | 198 |
| $c^\#$ | 259 | 265 | | 64 | 61 | 204 | 205 |
| c | 266 | 272 | | 70 | 67 | 209 | 212 |
| B | 273 | 280 | | 74½ | 72 | 215 | 218 |
| $B^b$ | 281 | 287 | | 80½ | 78½ | 221 | 225½ |
| A | 287½ | 294 | | 85 | 82½ | 227 | 232 |
| $G^\#$ | 295 | 301 | | 90½ | 88½ | 234 | 239 |
| G | 301½ | 309 | | 96 | 93 | 240 | 246 |
| $F^\#$ | 309 | 315 | | 102 | 99 | 247 | 252½ |
| F | 316 | 321½ | | 107½ | 105 | 254 | 260 |
| E | 322½ | 329 | | 113 | 111 | 260½ | 268 |
| $E^b$ | 330½ | 337 | | 118½ | 116 | 267 | 274 |
| D | 337 | 343 | | 125 | 122 | 275 | 282 |
| $C^\#$ | 344 | 350 | | 130 | 127½ | 283 | 290 |
| C | 352 | 357 | | 136½ | 134 | 289½ | 297 |
| BB | 358½ | 379 | | 142 | 139 | 297½ | 305 |
| $BB^b$ | 365 | 384 | | 149 | 146½ | 305½ | 314 |
| AA | 372 | 394 | | 155 | 152½ | 313 | 320 |
| $GG^\#$ | 379 | 400 | | 161½ | 159 | 320½ | 329 |
| GG | 387 | 407 | | 167½ | 165 | 328 | 337 |
| $FF^\#$ | 393½ | 415 | | 174 | 172 | 337 | 344 |
| FF | 401 | 422 | | 180 | 177 | 345 | 354 |

**Graph 6.2**
**Bridge pin, hitchpin and tuning pin positions of the 1743b HH**



## Table 6.2b
## Number of string pairs per Zoll for the 1743b HH

### Numbers of equally-spaced string pairs and the distance in Zolle occupied by them

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 12 in 2¼ | 12 in 5 1/3 | 36 in 30 6/19 | | | | |
| $e^3$ | | | | | | | |
| $e^{b3}$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^{\#3}$ | | | | | | | |
| $c^3$ | | | | | | | |
| $b^2$ | | | | | | | |
| $b^{b2}$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^{\#2}$ | | | | | | | |
| $g^2$ | | | | | | | |
| $f^{\#2}$ | 12 in 2¼ | | | | | | |
| $f^2$ | 12 in 2½ | | | | | | |
| $e^2$ | | | | | | | |
| $e^{b2}$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^{\#2}$ | | | | | | | |
| $c^2$ | | | | | | | |
| $b^1$ | | | | | | | |
| $b^{b1}$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^{\#1}$ | | | | | | | |
| $g^1$ | | | | | | | |
| $f^{\#1}$ | 12 in 2½ | | | | | | |
| $f^1$ | 12 in 3 1/3 | 12 in 5 1/3 | | | | | |
| $e^1$ | | 7 in 4 | | | | | |
| $e^{b1}$ | | | | | | | |
| $d^1$ | | | | | | | |
| $c^{\#1}$ | | | | | | | |
| $c^1$ | | | | | | | |
| b | | | | | | | |
| $b^b$ | | | | | | | |
| a | | | | | | | |
| $g^\#$ | | | | | | | |
| g | | | | | | | |
| $f^\#$ | 12 in 3 1/3 | | | | | | |
| f | 24 in 7 | | 36 in 30 6/19 | | | | |
| e | | | | 11 in 2 4/9 | | | |
| $e^b$ | | | | | | | |
| d | | 7 in 4 | | | 9 in 2 | 9 in 2¼ | 9 in 2½ |
| $c^\#$ | | 13 in 4 | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | 11 in 2 4/9 | 9 in 2 | 9 in 2¼ | 9 in 2½ |
| F | | | | 12 in 3 | 12 in 3 | 12 in 3 3/4 | 12 in 4 |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | | | | |
| C | | 13 in 4 | | | | | |
| BB | | 6 in 2 | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| $GG^\#$ | | | | | | | |
| GG | | | | | | | |
| $FF^\#$ | | | | | | | |
| FF | 24 in 7 | 6 in 2 | | 12 in 3 | 12 in 3 | 12 in 3 3/4 | 12 in 4 |

## Table 6.2c
## Marking-out stick divisions for the 1743b HH

### Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 16 in 3 | 9 in 4 | 19 in 16 | | | | |
| $e^3$ | | | | | | | |
| $e^{b3}$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^{\#3}$ | | | | | | | |
| $c^3$ | | | | | | | |
| $b^2$ | | | | | | | |
| $b^{b2}$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^{\#2}$ | | | | | | | |
| $g^2$ | | | | | | | |
| $f^{\#2}$ | 16 in 3 | | | | | | |
| $f^2$ | 24 in 5 | | | | | | |
| $e^2$ | | | | | | | |
| $e^{b2}$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^{\#2}$ | | | | | | | |
| $c^2$ | | | | | | | |
| $b^1$ | | | | | | | |
| $b^{b1}$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^{\#1}$ | | | | | | | |
| $g^1$ | | | | | | | |
| $f^{\#1}$ | 24 in 5 | | | | | | |
| $f^1$ | 18 in 5 | 9 in 4 | | | | | |
| $e^1$ | | 7 in 4 | | | | | |
| $e^{b1}$ | | | | | | | |
| $d^1$ | | | | | | | |
| $c^{\#1}$ | | | | | | | |
| $c^1$ | | | | | | | |
| b | | | | | | | |
| $b^b$ | | | | | | | |
| a | | | | | | | |
| $g^\#$ | | | | | | | |
| g | | | | | | | |
| $f^\#$ | 18 in 5 | | | | | | |
| f | 24 in 7 | | 19 in 16 | | | | |
| e | | | | 9 in 2 | | | |
| $e^b$ | | | | | | | |
| d | | 7 in 4 | | | 9 in 2 | 4 in 1 | 18 in 5 |
| $c^\#$ | | 13 in 4 | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | 9 in 2 | 9 in 2 | 4 in 1 | 18 in 5 |
| F | | | | 4 in 1 | 4 in 1 | 16 in 5 | 3 in 1 |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | | | | |
| C | | 13 in 4 | | | | | |
| BB | | 3 in 1 | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| $GG^\#$ | | | | | | | |
| GG | | | | | | | |
| $FF^\#$ | | | | | | | |
| FF | 24 in 7 | 3 in 1 | | 4 in 1 | 4 in 1 | 16 in 5 | 3 in 1 |

**Table 6.3a**
**Distance of the pins from the spine of the 1761a JH**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 36 | 36 | 756 | | | | |
| $e^{b3}$-$e^3$ | 42 | 43 | 726 | | | | |
| $d^3$ | 48 | 50 | 696 | | | | |
| $c^3$-$c^{\#3}$ | 55 | 58 | 665 | | | | |
| $b^{b2}$-$b^2$ | 61 | 64 | 632½ | | | | |
| $a^2$ | 68 | 73 | 600 | | | | |
| $g^2$-$g^{\#2}$ | 74½ | 80 | 566½ | | | | |
| $f^2$-$f^{\#2}$ | 81½ | 88 | 532½ | | | | |
| $e^{b2}$-$e^2$ | 89 | 95 | 498 | | | | |
| $d^2$ | 96 | 103½ | 464 | | | | |
| $c^2$-$c^{\#2}$ | 103 | 111 | 430 | | | | |
| $b^{b1}$-$b^1$ | 110 | 119½ | 395 | | | | |
| $a^1$ | 117 | 126 | 361 | | | | |
| $g^1$-$g^{\#1}$ | 124 | 134½ | 327 | | | | |
| $f^1$-$f^{\#1}$ | 132 | 141½ | 291 | | | | |
| $e^{b1}$-$e^1$ | 140 | 150 | 257½ | | | | |
| $d^1$ | 146½ | 157 | 222½ | | | | |
| $c^1$-$c^{\#1}$ | 155 | 165 | 182½ | | | | |
| $b^b$-b | 163 | 172½ | 152 | | | | |
| a | 171 | 180½ | 116½ | | | | |
| g-g# | 180 | 289 | 81½ | | | | |
| f-f# | 188 | 197½ | 46 | | | | |
| e | 197 | 208 | | 57½ | | | |
| $e^b$ | 206 | 217 | | 64 | | | |
| d | 214½ | 225 | | 70 | | | |
| c# | 223 | 234 | | 75½ | | | |
| c | 233 | 241 | | 81½ | | | |
| B | 241 | 251 | | 87½ | 84 | 199 | 201 |
| $B^b$ | 249½ | 260 | | 93 | 91 | 206 | 208 |
| A | 258 | 268 | | 99 | 96 | 213 | 217 |
| G# | 266 | 275 | | 105½ | 103½ | 220 | 224 |
| G | 274 | 283 | | 111½ | 108 | 228 | 231 |
| F# | 282½ | 290 | | 118 | 115 | 236 | 239 |
| F | 291 | 297 | | 123½ | 121 | 244 | 248 |
| E | 299 | 303½ | | 130 | 127½ | 252 | 256 |
| $E^b$ | 308 | 312½ | | 136½ | 133 | 260 | 265 |
| D | 316 | 319 | | 142½ | 140 | 268 | 273 |
| C# | 324½ | 327½ | | 148½ | 145½ | 277 | 281½ |
| C | 333 | 336 | | 155 | 152½ | 285 | 291 |
| BB | 344 | 377 | | 162 | 158½ | 294 | 301 |
| $BB^b$ | 353 | 382 | | 169 | 166 | 303½ | 309 |
| AA | 362 | 392 | | 176 | 172½ | 312½ | 318½ |
| GG# | 371 | 400 | | 183½ | 180 | 321½ | 327 |
| GG | 379 | 410 | | 190 | 187 | 331½ | 335½ |
| FF# | 387½ | 419 | | 198 | 195 | 341 | 345 |
| FF | 397 | 427 | | 205 | 203 | 350 | 355 |

**Graph 6.3**
**Bridge pin, hitchpin and tuning pin positions of the 1761a JH**

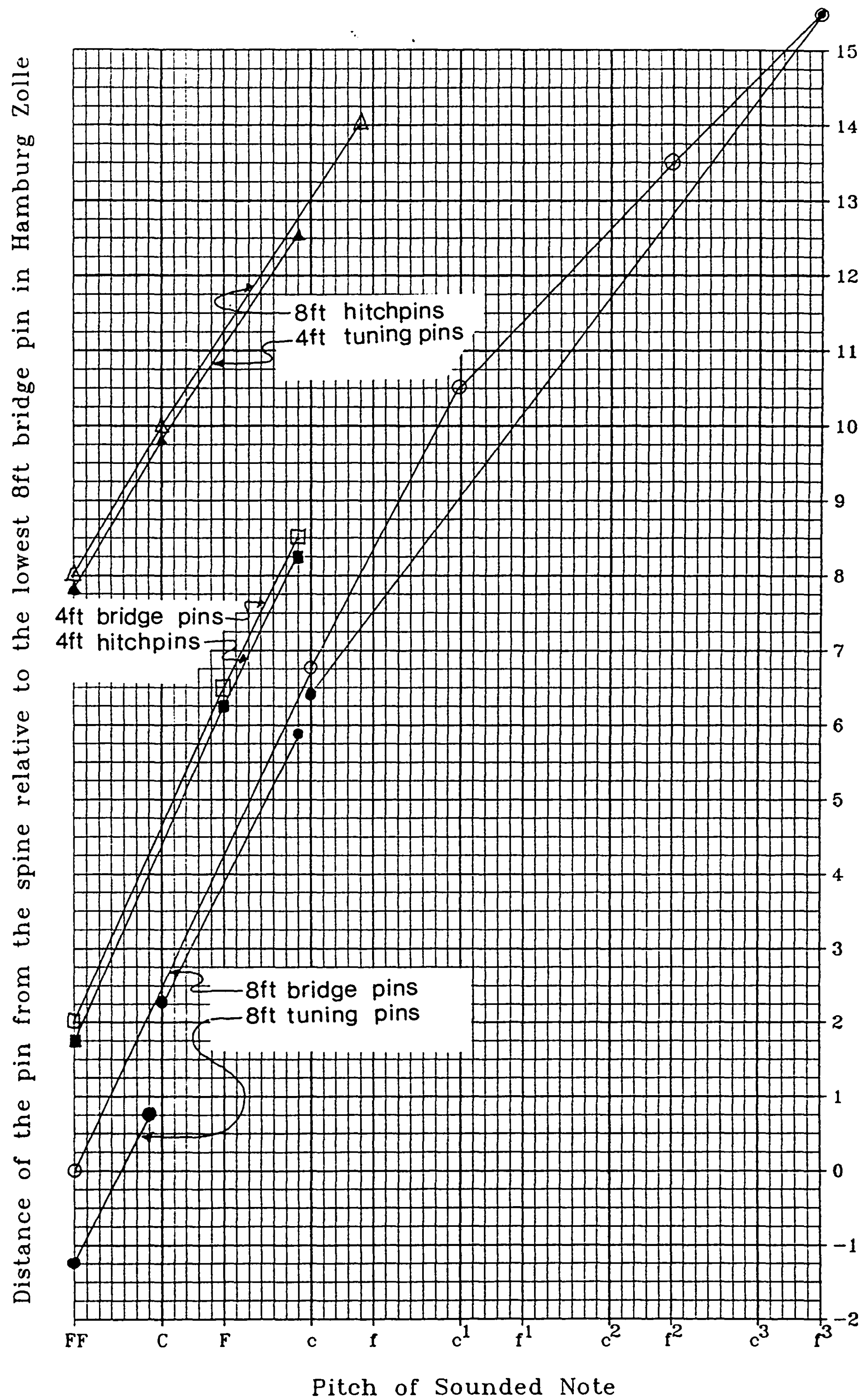


**Table 6.3b**
**Number of string pairs per Zoll for the 1761a JH**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 7 in 2 | 26 in $8\,^2/_3$ | 21 in $29\,^3/_4$ | | | | |
| $e^{b3}$-$e^3$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^3$-$c^{\#3}$ | | | | | | | |
| $b^{b2}$-$b^2$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^2$-$g^{\#2}$ | 7 in 2 | | | | | | |
| $f^2$-$f^{\#2}$ | 10 in 3 | | | | | | |
| $e^{b2}$-$e^2$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^2$-$c^{\#2}$ | | | | | | | |
| $b^{b1}$-$b^1$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^1$-$g^{\#1}$ | | | | | | | |
| $f^1$-$f^{\#1}$ | | | | | | | |
| $e^{b1}$-$e^1$ | | | | | | | |
| $d^1$ | 10 in 3 | | | | | | |
| $c^1$-$c^{\#1}$ | 9 in $3\,^3/_4$ | | | | | | |
| $b^b$-b | | | | | | | |
| a | | | | | | | |
| g-$g^\#$ | | | | | | | |
| f-$f^\#$ | | | 21 in $29\,^3/_4$ | | | | |
| e | | | | 16 in 4 | | | |
| $e^b$ | | | | | | | |
| d | | | | | | | |
| $c^\#$ | 9 in $3\,^3/_{14}$ | | | | | | |
| c | 19 in $6\,^{11}/_{14}$ | 26 in $8\,^2/_3$ | | | | | |
| B | | 11 in $3\,^2/_3$ | | | 11 in $2\,^3/_4$ | 6 in 2 | 6 in 2 |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | | | 6 in 2 | 6 in 2 |
| F | | | | | | 12 in 4½ | 12 in 4½ |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | 16 in 4 | 11 in $2\,^3/_4$ | | |
| C | | 11 in $3\,^2/_3$ | | 7 in 2 | 7 in 2 | | |
| BB | | 6 in 2 | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| $GG^\#$ | | | | | | | |
| GG | | | | | | | |
| $FF^\#$ | | | | | | | |
| FF | 19 in $6\,^{11}/_{14}$ | 6 in 2 | | 7 in 2 | 7 in 2 | 12 in 4½ | 12 in 4½ |

**Table 6.3c**
**Marking-out stick divisions for the 1761a JH**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 7 in 2 | 3 in 1 | 12 in 17 | | | | |
| $e^{b3}$-$e^3$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^3$-$c^{\#3}$ | | | | | | | |
| $b^{b2}$-$b^2$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^2$-$g^{\#2}$ | 7 in 2 | | | | | | |
| $f^2$-$f^{\#2}$ | 10 in 3 | | | | | | |
| $e^{b2}$-$e^2$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^2$-$c^{\#2}$ | | | | | | | |
| $b^{b1}$-$b^1$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^1$-$g^{\#1}$ | | | | | | | |
| $f^1$-$f^{\#1}$ | | | | | | | |
| $e^{b1}$-$e^1$ | | | | | | | |
| $d^1$ | 10 in 3 | | | | | | |
| $c^1$-$c^{\#1}$ | 14 in 5 | | | | | | |
| $b^b$-b | | | | | | | |
| a | | | | | | | |
| g-g# | | | | | | | |
| f-f# | | | 12 in 7 | | | | |
| e | | | | 4 in 1 | | | |
| $e^b$ | | | | | | | |
| d | | | | | | | |
| c# | 14 in 5 | | | | | | |
| c | 14 in 5 | 3 in 1 | | | | | |
| B | | 3 in 1 | | | 4 in 1 | 3 in 1 | 3 in 1 |
| $B^b$ | | | | | | | |
| A | | | | | | | |
| G# | | | | | | | |
| G | | | | | | | |
| F# | | | | | | 3 in 1 | 3 in 1 |
| F | | | | | | 8 in 3 | 8 in 3 |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| C# | | | | 4 in 1 | 4 in 1 | | |
| C | | 3 in 1 | | 7 in 2 | 7 in 2 | | |
| BB | | 3 in 1 | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| GG# | | | | | | | |
| GG | | | | | | | |
| FF# | | | | | | | |
| FF | 14 in 5 | 3 in 1 | | 7 in 2 | 7 in 2 | 8 in 3 | 8 in 3 |

# Chapter 7

# THE DECORATION OF HASS CLAVICHORDS

## INTRODUCTION

Hass clavichords are some of the most splendidly decorated of all stringed keyboard instruments. Perhaps the most characteristic style of case decoration is the black and gold chinoiserie on a red lacquer ground, normally used for the outside of the case and lid of Johann Hass instruments of the 1760's. The splendour of their decoration is probably a reason for the survival of a relatively large number of Hass's clavichords, since, after the clavichord's demise at the end of the eighteenth century, these instruments could still be treasured as a decorative piece of furniture.

It is necessary to discuss the decoration of Hass harpsichords alongside that of the clavichords for two reasons. First, it is likely that the Hass family employed the same craftsmen to paint the harpsichords as they did to paint the clavichords. The soundboard painting of the 1763a JH clavichord and the 1764 JH harpsichord were, for example, probably executed by the same person. Second, although there are only a few surviving harpsichords by the Hass family they tend to retain their original decoration. Since the outside of the case and lid of many of the clavichords have been painted over, the harpsichords give a good idea of how some of the clavichords must have looked when they were first made.

A number of criteria have been used in deciding whether or not an instrument is preserved in its original decorative state. The outer cases of a number of instruments, such as the 1740a HH, the 1746 JH and the 1755 JH have been painted very crudely, with splashes of paint on the arcades, mouldings and hinges. The present paintwork on these instruments is, therefore, of a later date and obscures the original paintwork. Layers of paint and variations in its colour on different parts of the outer case and lid can also help in deciding the authenticity of the decoration. When several instruments have the same decoration, such as the 1761c JH, the 1762 JH, the 1763a JH and the 1763b JH, or where two clavichords have the same lid painting it must be original.

## THE DECORATION OF PRE-HASS CLAVICHORDS

Although the cases of many seventeenth- and early eighteenth-century harpsichords are elaborately decorated, early clavichords tend to be very simply decorated or not at all. Cheap clavichords made from pine were painted with a brown or black pigment, and more expensive instruments made from walnut were simply varnished to show the natural beauty of the wood. The lack of decoration of these early clavichords must surely reflect the attitude of both the maker and the musician towards the clavichord. If, as many writers have suggested[1] the clavichord was used primarily (before 1700) as a practice instrument by organists there would have been no reason for an expensive lid painting, since the instrument was purely functional. This attitude, that the clavichord was practical rather than decorative, may also have prevented many seventeenth- and early eighteenth-century makers from signing their instruments. Only when the ownership of an instrument is seen as an expression of wealth and status can there be enough stimulus for elaborate case decoration.

At the beginning of the eighteenth century, a change of attitude towards the clavichord (and therefore in its status) appears to have taken place in what is now Germany, for instruments start to be decorated, signed and dated. Christoph Rueger[2] has pointed out that the clavichord does in fact have large rectangular surfaces, the case sides, lid and soundboard, which are very suitable for decoration.

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1 For example R. Russell, *The Harpsichord and Clavichord*, 2nd ed. (London: Faber & Faber, 1973), p.98.

One of the first to realize the clavichords decorative potential was the Leipzig maker Johann Jacob Donat. The outer case, toolbox lid, keywell cheeks and the nameboard of the clavichord made in Leipzig in 1700 by Donat[3] are decorated with small panels of tortoise-shell, a material very much in vogue at this time.

Many clavichords built during the eighteenth century were elaborately decorated in accordance with the current fashions of interior design. The degree of elaborateness was obviously dependent on the wealth of the buyer. When fashions changed the case was simply overpainted in the new style. Both of the C to $d^3$ Fleischer clavichords examined have, for example, been crudely overpainted, but the present imitation tortoise-shell casework decoration of the 1723 JF does, although not original, blend in with the real tortoise-shell veneer on the natural keylevers, the nameboard and the toolbox lid.

## THE ROCOCO STYLE OF INTERIOR DECORATION

The Rococo style of interior decoration and design,[4] which dominated Europe from about 1715 to 1765, owed much to the stimulus of the Regency of the Duc d'Orleans. The principal designer, who was largely responsible for its development, was Juste-Aurèle Messonnier (1693 or 1695 to 1750), goldsmith and interior designer to Louis XV. The style was based on asymmetrical design and included such forms as the C-scroll, scrolled foliage, shells and floral motifs, whilst in furniture manu-

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2 C. Rueger, *Musical Instruments and Their Decoration* (Newton Abbot: David & Charles, 1986), p.13.

3 H. Henkel, *Clavichorde, Musikinstrumenten-Museum der Karl-Marx Universität, Katalog, Band 4* (Leipzig: VEB Deutscher Verlag für Musik, 1981), Cat. No.12, pp.37-8.

4 The term 'Rococo' is rarely used in music. Although some music of the first half of the eighteenth century has been described as Rococo, it is more appropriately described as 'galant'.

facture the use of the cabriole or reverse curve became the favoured form for the legs of tables, cabinets and chairs from about 1725.

A major aspect of the Rococo period was the passion for Chinese art objects. Although the Portuguese had imported some Chinese porcelain, silk and lacquer-work during the Renaissance period, the articles were too expensive to create any real vogue in Europe. It was not until the trading of the Dutch East India Company became so intense in the seventeenth century that Chinese goods became fashionable and large profits could be made from their importation. In the period 1603-1693, for example, the Dutch East India Company imported oriental goods from the Far East to the annual value of 120 million *livres*.[5] To satisfy the demands of less affluent members of society European craftsmen were kept busy imitating not only Chinese hard-paste porcelain (for example at Meissen, Delft, Sevres and Hamburg) and oriental lacquer, but also the actual designs found on the imported cabinets, porcelain and embroideries.

To help European craftsmen imitate oriental products many books of oriental designs were published. The most famous seventeenth-century English book on the subject, *A Treatise on Japanning and Varnishing* by Stalker and Parker, was published in London in 1688. During the Rococo period the number of publications of chinoiserie designs increased markedly. Augsburg and Nuremburg were the two great print-producing centres in Germany, and many chinoiserie designs (such as those by Paul Decker) were disseminated from there. The eighteenth-century artists modified the designs of the imported lacquers by introducing European figures, draperies, arabesques and exotic animals such as monkeys. Also, in place of the conventional black and gold of the Oriental products came a wide choice of background

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[5] A. Reichwein, *China and Europe: Intellectual and Artistic Contacts in the Eighteenth Century* (London: Routledge & Kegan Paul Ltd, 1968), p.16.

colours, including vermilion, white, blue and green. In the eighteenth century, bookcases, desks, long case clocks and tables were all lacquered and decorated with chinoiserie.

Probably because of its trading connections, Hamburg was one of the first settlements within the Holy Roman Empire in which lacquer masters practised their skills. According to Conradt[6] the tradition for lacquering furniture in Hamburg dates from at least the second decade of the 17th century. In the Hamburg city archives, for example, we learn of an *Indianischer Lackwerker*,[7] one Evert Sachsenhausen in July 1622 and of another lacquerer, one Marcus Albrecht in the period 1641-57. By the end of the seventeenth century, Hamburg lacquered furniture was being exported all over Europe. The 1689 inventory of the Electress Dorothea, wife of Frederic William of Brandenburg, for instance, mentions 'Hamburg lacquer trays on stands with turned columns.'[8] Conradt gives the names of three lacquerers working in Hamburg during the eighteenth century, any one of whom may have been responsible for the lacquerwork on Hass instruments. These are: Philip Jacob Otto, Ludewig Bannier and Ernst Gotthilf Quinckhardt.[9]

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[6] A. Conradt, "Hamburger Musikinstrumente des 18. Jahrhunderts mit Lackmalerei," *Jahrbuch der Hamburger Kunstsammlungen*, IX (Hamburg: Hauswedell, 1964), pp.29-48.

[7] During the 17th century Indian probably simply meant exotic, mostly Chinese.

[8] H. Huth, *Lacquer of the West: the history of a craft and an industry 1550-1950* (Chicago: University of Chicago Press, 1971), p.63.

[9] A. Conradt, "Hamburger Musikinstrumente des 18. Jahrhunderts mit Lackmalerei," *Jahrbuch der Hamburger Kunstsammlungen*, IX (Hamburg: Hauswedell, 1964), p.48.

## CHINOISERIE DECORATION OF HASS CLAVICHORDS AND HARPSICHORDS

Chinoiserie decoration appears to have been an option for all potential buyers of Hass harpsichords and clavichords. Chinoiserie was certainly not confined to any one period of instrument production, but can instead be found on instruments ranging in date from 1721 to 1763. It is usually the interior of the lid, rather than the outer case and exterior of the lid which is decorated in chinoiserie. The outer case and lid of only two Hass harpsichords (the 1723 HH and the 1732a HH) and one clavichord (the 1763a JH) are decorated in chinoiserie, whereas the lid interior of six clavichords (the 1740a HH, the 1746 JH, the 1755 JH, the 1761c JH, the 1762 JH and the 1763b JH) and three harpsichords (the 1721 HH, the 1732a HH and the 1760a JH) are decorated in this way.

It is unlikely that the same craftsman (or even workshop) would have been involved in the decoration of Hass instruments for the entire forty-year period. Indeed, the variable quality and style of the outer-case chinoiserie on the 1723 HH (see plate 7.1) and the 1732a HH (see plate 7.2) harpsichords, has led Huth[10] to conclude that the decoration was executed by two different craftsmen:

> One instrument, made about 1723, [the 1723 HH harpsichord] is decorated with a scene of more or less European figures clothed in a kind of Chinese garb against a background of naïvely drawn buildings and plants. In strong contrast to this design is that by another artist, around 1732-55, who was more skilful and had a knowledge of Far Eastern patterns. He makes a sincere attempt to depict rocks, plants, houses and a few scattered figures in a truly Chinese pattern, though the result is a chinoiserie of so individual a style that his work is easily recognizable.

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[10] H. Huth, *Lacquer of the West: the history of a craft and an industry 1550-1950* (Chicago: University of Chicago Press, 1971), p.63.

**Plate 7.1 The 1723 HH harpsichord**

Copyright, Musikhistorisk Museum og Carl Claudius' Samling, Copenhagen.
Photograph by Ole Woldbye.

Both the 1732a HH harpsichord and the 1755 JH clavichord appear to have been decorated in the same workshop. The lid interior of the 1732a HH and the 1755 JH is decorated with chinoiserie in red, yellow, green and black on a lacquered yellow ground. The ground may, however, have originally been white but has since turned yellow. According to Bourne and Christie[11] only the white lacquer pieces of Gérard Dagly (1657-1726), *Intendant des Ornaments* to Frederick I of Prussia from 1696, have not turned yellow with age. The decoration on the lid interior of both the

[11] J. Bourne et alia, *Lacquer; An International History and Collector's Guide* (London: Bracken Books, 1989), p.199.

1732a HH and the 1755 JH is made up of many stylised Oriental elements: Chinamen crossing a bridge, curve-roofed buildings, lattice-work fences, rocks, ornamental trees, birds and moths.

**Plate 7.2 The 1732a HH harpsichord**
The outer case, lid and stand are sumptuously decorated with Chinese figures, rocks, pagodas, exotic birds and moths.

**Plate 7.3**
**Detail from the lid interior of the 1755 JH**

It is probable that there were also two other workshops involved in the chinoiserie of Hass instruments. The style of the raised chinoiserie on the lid interior of the 1721 HH in gold, red, black and silver (for the hands and faces) on a vermilion ground is of a highly individual character, and was probably painted in a different workshop from that of the 1723 HH, the 1732a HH, or the 1755 JH. The stunning decoration on the 1721 HH does in fact include some elements (such as the Chinaman riding on the back of an ibis) which are not to be found on any other surviving Hass instrument. However, some of the elements (such as the small birds and the moths) are also to be found in the chinoiserie on the 1732a HH and the 1755 JH, as well as the chinoiserie on the clavichords dating from the 1760's. The different painters must, therefore, have had access to some of the same pattern books.

**Plate 7.4**
**Detail from the lid interior of the 1721 HH**

**Plate 7.5**
**Detail from the lid interior of the 1721 HH**

The fourth style of chinoiserie is represented by the 1760a JH harpsichord and the 1761c JH, the 1762 JH, the 1763a JH and the 1763b JH clavichords. The style bears some resemblance to that of the 1732a HH and the 1755 JH, but is far less elaborate. It consists of gold and black chinoiserie on a red-lacquered ground surrounded by an elaborate border pattern. The lid designs of all four clavichords have many elements in common with each other, albeit arranged slightly differently. The same type of foliage, buildings, rocks, groups of birds and insects appears on all of them. This probably indicates that they were all decorated by the same hand or at least in the same workshop. The similarity of the birds and moths, in particular, may mean that they were traced. A method entitled 'To take off any Japan-patterns in this Book, upon any piece of work whatsoever', is described in Stalker and Parker:[12]

> When your Black, or any other colour is varnished and polish't fit for draught, take a particular design out of this Book, or any thing else that is drawn upon paper, with whiting rub all over the back-side of your Print or Draught, and use a linnen cloth to wipe off all the whiting that lies rough and dusty on the back-side of your paper so whited. Then lay the Print on the Table or Box, with the whited side next to it, in the very place where your design the Draught should be made, and with a needle or piece of iron-wyer round and smooth at the point, fixed in a wooden handle for the purpose, not sharp to cut or scratch your Paper and Print, which we call a Tracing-pencil; with this, I say, draw over and trace the Print as much as you think necessary, taking the most material and outward stroaks, or all others which you imagin are hard and difficult to draw without a pattern. This, by the assistance of the whiting with which your paper was rubb'd, will give the fashion and lines of what you have done, upon the Box or Table.

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[12] J. Stalker & G. Parker, *A Treatise of Japanning and varnishing* (London, 1688; facsimile edition, London: Alec Tiranti, 1960), p.39.

**Figure 7.1**
**The moth and three birds used in the chinoiserie designs**
(Scale 1:1)

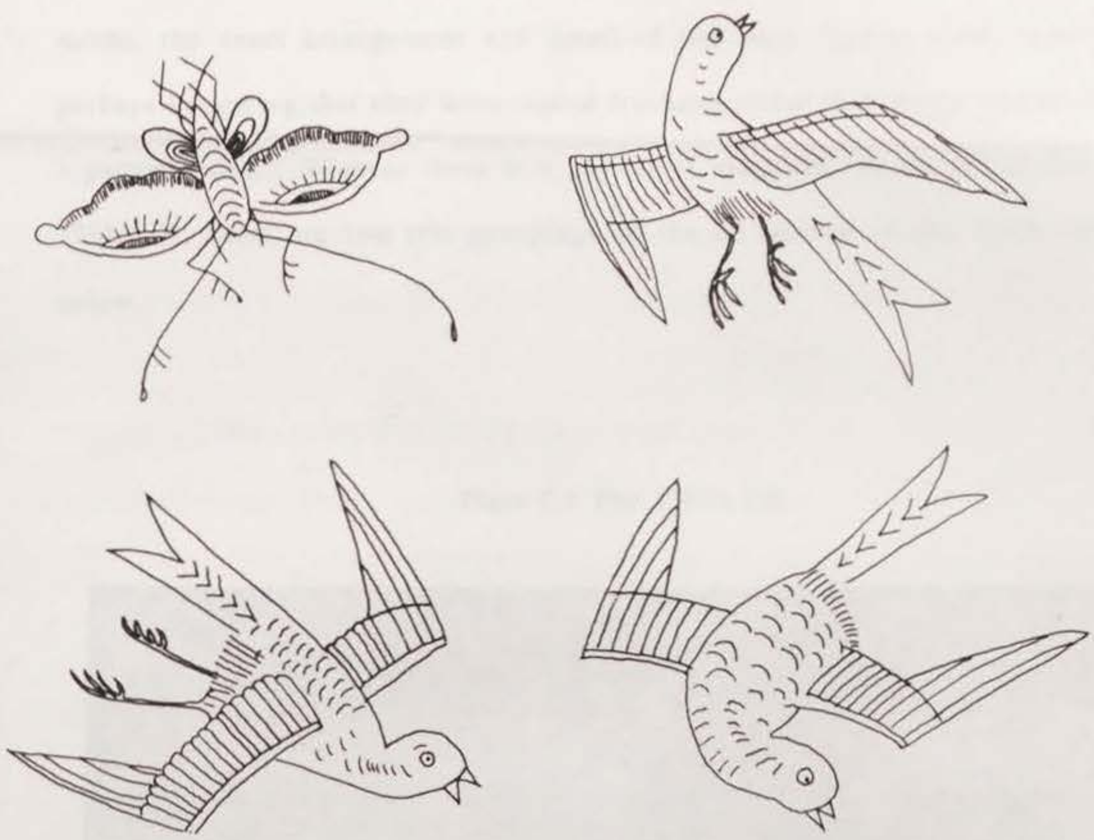

**Plate 7.6**
**Chinoiserie detail from the right-hand case front of the 1763a JH**

A new element in the chinoiserie of these later instruments is the groups of musicians playing a variety of highly stylised musical instruments: flute, double bass, trumpet, violin, harp and long-necked lute. In contrast to the birds and moths, the exact arrangement and detail of the these figures varies considerably, perhaps indicating that they were copied freehand rather than being transferred from a pattern book. Whereas there is a quintet of musicians on the lid interior of the 1761c JH, there are two trio groupings on the lid interior of the 1763b JH shown below.

**Plate 7.7 The 1763b JH**

According to the MacTaggarts[13] as many as ten applications of vermilion lacquer was applied to the wood surface of the 1761c JH to form an opaque colour coat filling the grain. The lid was then varnished and the chinoiserie design painted on in black-pigmented adhesive. To this, gold leaf (for the border pattern and much of the central design), bronze powder (for the rocks and ground) and silver powder (for the hands and faces) was applied while it was still tacky. Fine detail was then drawn on with a pen and the whole of the lid then varnished to protect it and reduce the speed at which the silver and bronze tarnish.

## OTHER TYPES OF OUTER-CASE DECORATION

### Imitation tortoise-shell

A type of outer-case decoration nearly always used in combination with a lid interior decorated with chinoiserie is the mottled brown effect, in imitation of tortoise-shell (see plate 7.7 above). Simulated tortoise-shell was in fact quite common in the eighteenth-century and is found on a wide range of furniture types of the period, such as a tables, chests, and even long-case clocks such as that made in London about 1755 by Bartholomew Barwell.[14] In Hamburg this style of decoration must have been very popular in the eighteenth century, for the outer case and lid of several keyboard instruments are decorated in this manner. For example, the 1618 double-manual harpsichord by Johannes Ruckers, re-made in Hamburg in 1724 by Johann Fleischer is painted in simulation of tortoise-shell, as is the outer-case and lid of four Hass instruments: the 1740c HH and the 1760a JH harpsichords; and the 1761c JH and the 1763b JH clavichords.

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[13] A. & P. MacTaggart, "Restoration report on the clavichord built in 1761 by Johann Hass," in the possession of Christopher Hogwood.

[14] The clock is illustrated in J. Bourne et alia, *Lacquer; An International History and Collector's Guide* (London: Bracken Books, 1989), p.214.

### Black lacquer and wood-graining

The casework of several clavichords is painted very simply. The (1725) HH was, for example, originally painted a light green whilst three clavichords (the 1743a HH, the 1744a HH and the 1760b JH) are lacquered black. Black lacquer pieces were in great demand in Europe in the eighteenth century, since black was the colour of the majority of the pieces imported from the Orient. There are, however, no Hass instruments which have chinoiserie on a black lacquer ground.

The outer cases of eight Hass clavichords are presently painted with a red-brown pigment, which is either an iron oxide red or a burnt umber. These are: the 1732b HH, the 1742a HH, the 1742b HH, the 1744b HH, the 1746 JH, the 1748 JH, the 1761b JH and the 1767 JH. However, the present outer-case decoration of all these instruments, except for that of the 1767 JH, obscures the original paintwork. For example several of the instruments preserved in Scandinavian countries, such as the 1746 JH, were probably painted with their present wood-grain decoration in the nineteenth century. This is not to say that Hass clavichords were never originally painted very plainly with an iron-oxide pigment, since the clavichord built in 1756 in Hamburg by Johann Gerlach was originally decorated in this manner. I know of only one Hass clavichord, the 1767 JH, with authentic wood-graining. The outer-case and lid of the 1767 JH is painted in panels in imitation of mahogany, and with border cross-banding in imitation of walnut.

## OTHER TYPES OF LID-INTERIOR DECORATION

### Paintings

The lid interior of most Hass clavichords was originally decorated either with chinoiserie, or with a painting depicting some type of musical subject matter. Perhaps as a reflection of the wealth of the original buyer, the size and quality of the lid painting is variable. Some, such as the lyre-player riding a dolphin on the lid interior of the 1728 HH (see plate 7.8) or Orpheus surrounded by some of the muses on the lid interior of the 1743a HH occupy only a small central part of the lid and act as a focal point for the whole instrument. Others, such as the lid paintings of the 1743b HH and the 1744b HH (see plate 7.9), which depict six of the muses in a rocky landscape, fill the entire surface of the lid. It is interesting that the lid paintings of the latter two clavichords are exactly the same. This may indicate that there were a number of set lid paintings from which a customer could choose. The 1742a HH has a particularly charming lid painting consisting of three pairs of musicians: a flautist and singer, a zither-player and piper, and a male singer with a female clavichord player. Although the clavichord depicted is not painted in true perspective it does appear to be a Hass instrument painted in vermilion and supported by a stand with cabriole legs. Although competently painted none of the lid paintings is of great artistic merit, and were probably executed by craftsmen rather than by fine artists.

**Plate 7.8 The 1728 HH**

**Plate 7.9 The 1744b HH**

The interior decoration of Hass harpsichord lids is usually of a higher quality than that of the clavichords. The lid painting of the 1734 HH for example, depicting the 'Trojan Horse' is particularly striking. Alexander Pilipczuk[15] has discovered that the pen-and-ink drawing by Bernard Picart used for his engraving entitled 'Grand Concert dans un Jardin' (Paris, 1709) was used as the basis of the main lid painting of the 1723 HH harpsichord. An original engraving is preserved at the Gementemuseum, Den Haag and depicts an open air courtly concert exemplifying the 'ludus artis'. The central group of the grand concert was often copied by other artists during the eighteenth century. The lid painting of the clavichord made in Stockholm in 1736 by Erich Månsson German,[16] for example, also uses this scene.

[15] A. Pilipczuk, "The Grand Concert dans un jardin by Bernard Picart and the performing musical arts at the French Court around 1700," *Tijdschrift van de Vereniging voor Nederlandse Muziek Geschiedenis*, XXX (1980), pp.121-47.

Furthermore, a copper cup by Johann Priester the Elder (1658-1726) of Augsburg, preserved at the Museum für Kunst und Gewerbe in Hamburg, has an enamel painting of the four central figures of the engraving.

**Plate 7.10**
**Central group of musicians from the lid interior of the 1723 HH**

**Engravings**

The lid interiors of two clavichords are decorated with eighteenth-century engravings. Most of the lid of the 1744a HH is taken up with a large engraving by Philipp Oeding (1697-1781) entitled 'Prospekt Der Daenischen Handels-stadt Altona, von Süden Gesehen 1746.'[17] Since the engraving was made two years later than the clavichord it cannot be original to the instrument. Below the main engraving there there are five smaller pages of engravings, with each of the five pages showing

[16] E. Helenius-Öberg, *Svenskt Klavikordbygge 1720-1820* (Stockholm: Almqvist & Wiksell International, 1986), p.121.

[17] I have discovered that this engraving is also preserved at the Altona Museum, Hamburg, inv.no.AB 2689/1.

seven musicians. These engravings have been identified by Alfred Berner[18] as being from a loose-sheet edition printed by Christoph Weigel of Nuremburg, entitled *Musicalisches Theatrum*. The exact date of the edition is not known, but it is thought to be after 1725. In addition to these engravings the lid interior of the 1744a HH is also decorated with a number of miscellaneous engravings, which I have not been able to identify.

**Plate 7.11 The 1744a HH**

Copyright, A.C.L., Brussels.

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[18] *Johann Christoph Weigel Musicalisches Theatrum*, facs. ed. by Alfred Berner (Basel: Bärenreiter Kassel, 1964), pp.viii-ix.

The upper-half of the lid of the 1761b JH is decorated with eight separate portraits of Swedish, Austrian and Danish Kings and Queens. These include Maria Theresa, Empress of Austria (reigned 1740-1780) and her son, Joseph (later Joseph II), Adolphus Frederick of Sweden (reigned 1751-1771) and his wife Queen Louisa Ulrika, Frederick V of Denmark-Norway (reigned 1746-1766) and his wife Juliane Marie of Brunswick. The lower-half of the lid is decorated with six separate engravings depicting blood sports, such as bear-baiting and stag-hunting. All the engravings on this instrument have been naively painted, presumably by an owner. Since the engravings are poorly arranged on the lid, and part of the lid behind the engravings is actually visible the engravings are unlikely to be original to the instrument.

**Plate 7.12 The 1761b JH**

## SOUNDBOARD DECORATION

### Flower painting

Only five Hass clavichords do not have painted soundboards. These are the 1742b HH, the 1743a HH, the 1743b HH, the 1760b JH and the 1767 JH. The soundboards of the remaining instruments are decorated with a variety of stylised flowers, such as parrot-tulips, carnations, anemones, bluebell-like flowers and fresias. As in other cities at this time, the wealthy citizens of Hamburg collected rare and exotic plants. Handel (1685-1759), for example, is known to have sent at least two crates of plants to Telemann, one in the year 1750 and one in the year 1754.[19] In addition to flowers the soundboard of the 1740a HH is decorated with a painting of a female lutenist. Although this is the only Hass clavichord with a figure painted onto the upper surface of the soundboard, Hieronymus Hass harpsichords have one or more figures in Roman-style costume or armour facing the player at the front left-hand corner of the soundboard.

**Plate 7.13**
**One of the anemone-like flowers on the soundboard of the 1732b HH**

[19] R. Petzoldt, *Georg Philipp Telemann* (London: Ernest Benn Ltd, 1974), pp.63-4.

**Plate 7.14**
**Typical layout of flowers on the soundboard of a Hass clavichord**
(modern copy by the author, with the soundboard painted by Jenny Nex)

According to Anne and Peter MacTaggart[20] the paint was applied directly onto the soundboard without any underpainting of glue or gum size to make the wood less absorbent. An underpainting of some sort must have been applied, however, to prevent the colours from running along the pores of the wood. The pigments used in the soundboard painting of the 1761c JH have been analysed by the MacTaggarts and found to be: lead white, yellow ochre, blue verditer, red lake, iron oxide red and calcite (chalk).

**Signature**

The clavichords of Hieronymus and Johann Hass are usually signed in black ink on the soundboard between the 8ft bridge and the 8ft tuning pins. Only the 1767 JH, which is signed in red ink, differs from the standard practice of using black-coloured ink. The signature always includes the name of the maker, the city in which the clavichord was made and the date of construction. On the soundboard of the 1740a HH the signature is written in a continous line, but in all other cases the signature is written on two lines. The name Hieronymus Albrecht Hass appears in full on the 1732b HH. Usually, however, Hieronymus Albrecht Hass is abbreviated to 'Hieronym. Albr. Hass.' Johann Adolph Hass is always abbreviated to simply 'J. A. Hass.' The name Hamburg appears in full on the 1744b HH, but is more commonly abbreviated to either 'Hamb.', 'Hambg.', or 'Hambr.'

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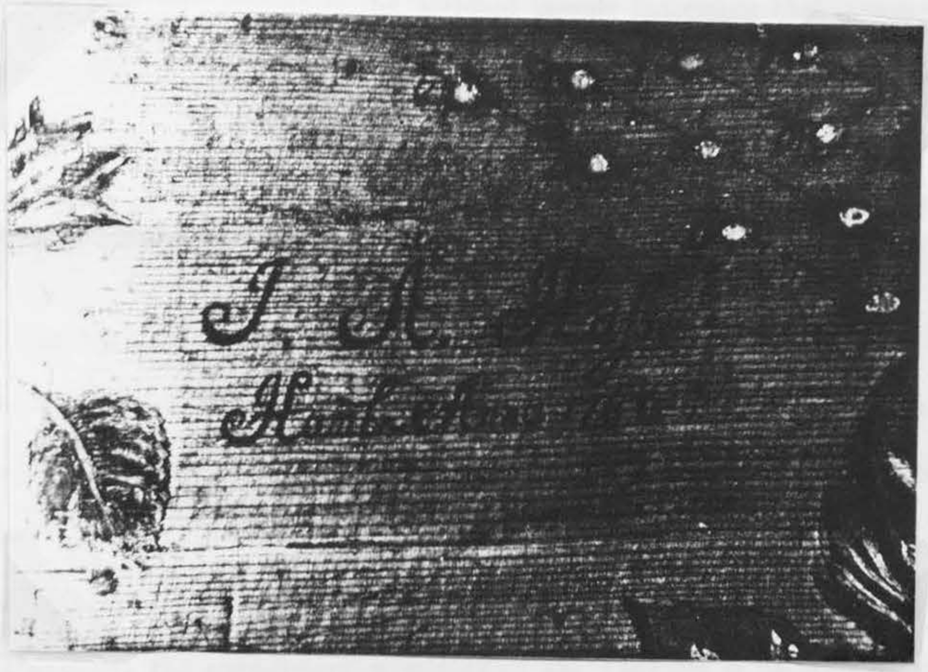
20 A. & P. MacTaggart, "Restoration report on the clavichord built in 1761 by Johann Hass," in the possession of Christopher Hogwood.

**Plate 7.15 The signature on the soundboard of the 1761c JH**



Photograph by Peter and Anne MacTaggart.

## MOULDING DECORATION OF CLAVICHORDS

The edge of the baseboard is painted in the same manner as the outer case, except for the moulded part which is gilded. The top edge of the case sides is usually painted red (probably with vermilion) and the ogee moulding is gilded. Only the rosewood case-top moulding of the 1763a JH is not gilded. Instead it is varnished to show the natural beauty of the wood.

All Hass clavichords have a small internal liner around the edge of the soundboard. In all but the 1767 JH this liner is painted red and the moulded part is gilded. The red pigment and gilding on a small piece of broken soundboard moulding of the 1756 JG clavichord was analysed using X-ray fluorescence at the Conservation and Research Laboratories, National Museums of Scotland as part of the instrument's investigation by Grant O'Brien.[21] The results showed that a high level of mercury was present in the pigment sample indicating that it was vermilion (mercuric sulphide). The gilt on the shaped part of the soundboard moulding of the 1756 JG was found to be in the form of brass foil rather than actual gold. X-ray fluorescence of the brass showed it to have a very high copper content of 92.8% and only 7.2% of zinc, rather than the more usual composition of 70% copper and 30% zinc. The high copper content meant that the brass was more malleable, and therefore better able to be used as a gilding metal than normal brass which has a higher zinc content. Although neither the pigment nor the gilding on the soundboard mouldings of Hass clavichords have been scientifically analysed, it is likely that they are decorated using both vermilion and brass leaf in the same manner as the 1756 JG. Unusually the soundboard moulding of the 1767 JH is of walnut rather than the more usual pine, and is left unpainted and ungilded.

**SOUNDWELL AND KEYWELL DECORATION**

The interior case sides of the clavichord above the soundboard, rack and 4ft wrestplank are usually painted in vermilion. In most cases, the left-hand side of the treble keywell brace above the mousehole is also painted in vermilion. It is also used to paint the top surface of the bass keywell brace of the C to $d^3$ models, and the capping piece between the bass keywell brace and the 4ft wrestplank of the FF to $f^3$ models. The sides of the keywell above the keylevers, the front of the nameboard and the inside surface of the keywell flap are either painted vermilion or veneered in vertical-grained olive wood.

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21 G. O'Brien, "Investigative Analysis of Unfretted Clavichord by I.C. Gerlach, Hamburg, 1756," held at Ringve Museum, Trondheim, with copies at the Russell Collection (Edinburgh, 1990), pp.5-8 and 24-5.

The decoration of the 1763a JH is particularly well preserved. The soundwell and keywell are veneered in olive wood, whilst the veneer above the mousehole and that used as a capping piece between the left-hand brace and the 4ft wrestplank is Kingwood. The front of the nameboard of the 1740a HH is decorated in parquetry of olive wood, tortoise-shell, ivory and engraved squares of mother-of-pearl.

**4FT WRESTPLANK AND RACK**

Both the rack and the 4ft wrestplank are usually veneered in walnut. The 1763a JH is unusual in that both the rack and the 4ft wrestplank are veneered in Kingwood. The 4ft wrestplank of most clavichords is decorated with a stopped chamfer about 5 Zolle long cut into the top right-hand edge. There is a also a much smaller stopped chamfer worked into the top edge of the toolbox backing piece. Rather than a stopped chamfer, both the 1740a HH and 1763a JH have a small bead moulding let into the top edge of the 4ft wrestplank and the front edge of the rack. On the 1763a JH this is of rosewood, while the bead moulding of the 1740a HH is in a chevron pattern made from ebony and ivory. The bead moulding on both the 1740a HH and the 1763a JH is unpainted and ungilded.

**THE TOOLBOX LID**

One of the characteristic features of Hass clavichords is the chamfered toolbox lid decorated in parquetry with a variety of exotic woods and materials. The most common materials used are ivory, ebony and walnut, but Hass also made use of white mother-of-pearl,[22] tortoise-shell[23] and olive wood. A catalogue of a select number of designs is given below. Ebony is shown in black, walnut in hatched

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[22] Several types of shell are used for the making of mother-of-pearl. The white-coloured nacre used by Hass is similar to the type used for the making of pearl buttons, which is derived from the button shell (*Umbonium giganteum*).

lines, tortoise-shell in dots and ivory in white. Where mother-of-pearl is used it is specified.

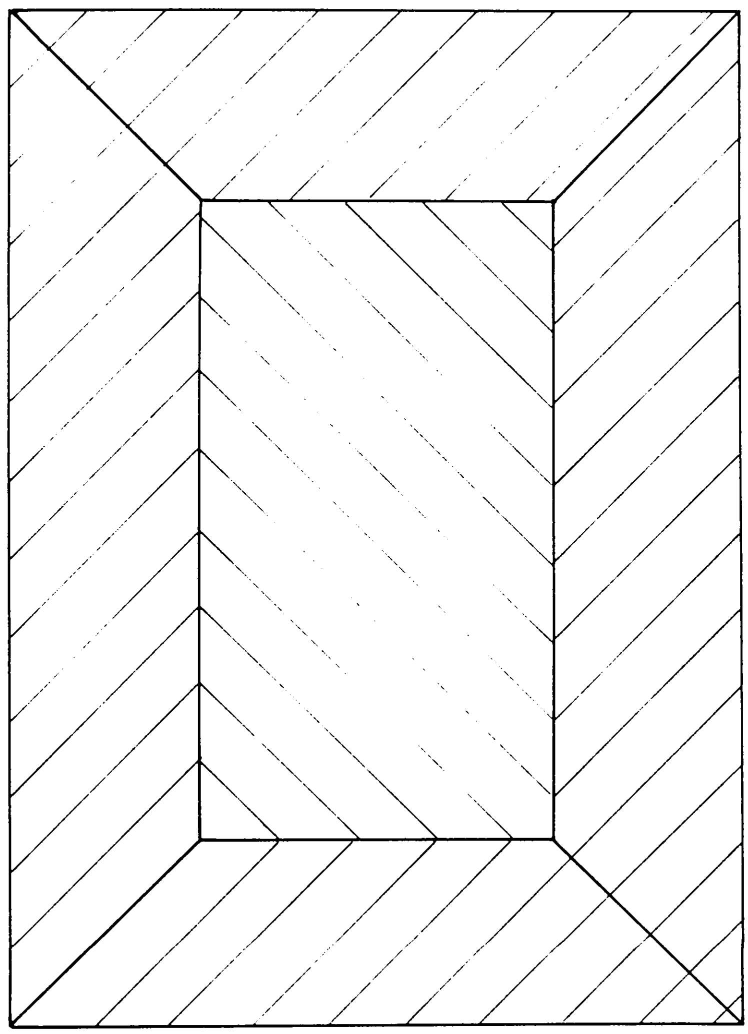

**Figure 7.2 Toolbox lid of the 1740b HH and the (1725) HH**
This is the simplest design, using only walnut.
Scale 1:1

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23 Tortoise-shell is a compound of keratin, hydrogen and hydroxyl, similar in nature to the horns and hooves of mammals. It is produced from three species of marine turtle, the most important of which is the Hawksbill (*Chelone imbricata*).

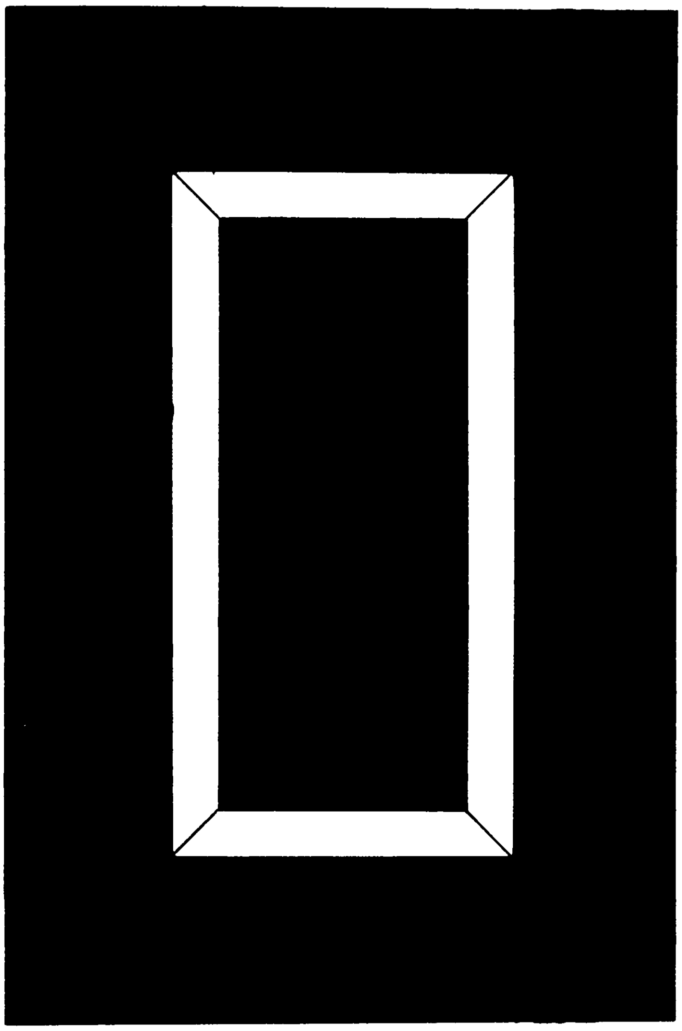


**Figure 7.3 Toolbox lid of the 1761a JH**

This design, of ebony and ivory, is also used for the 1761c JH and the 1762 JH.
Scale 1:1

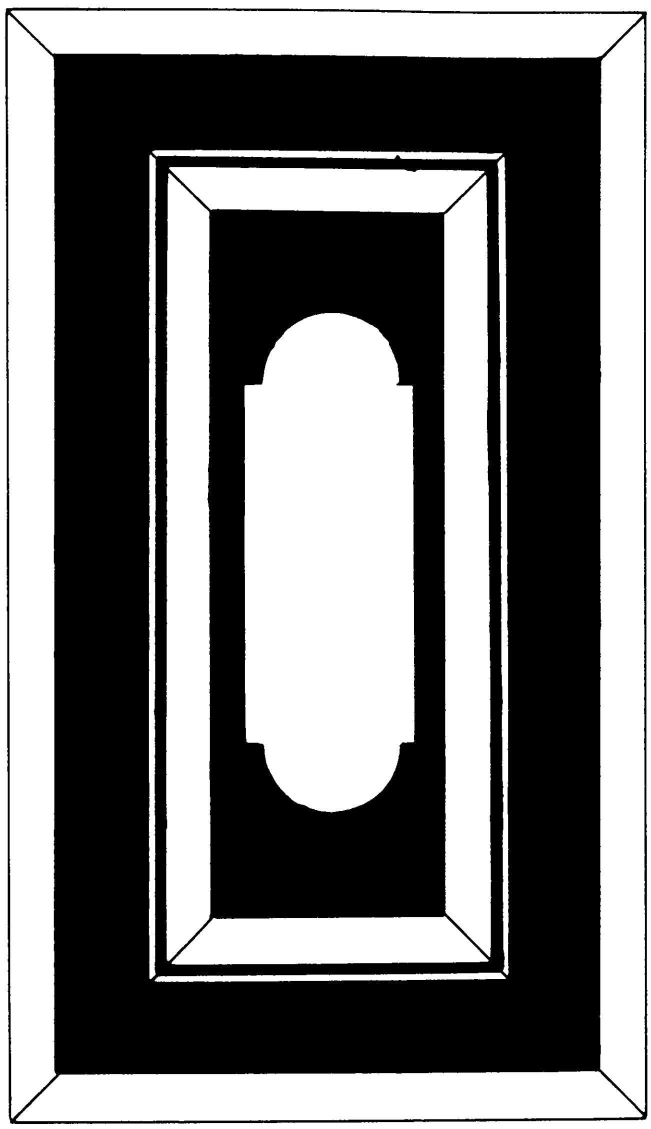


**Figure 7.4 Toolbox lid of the 1743b HH**

Design of ebony and ivory, with an ivory moulding around the edge.
Scale 1:1

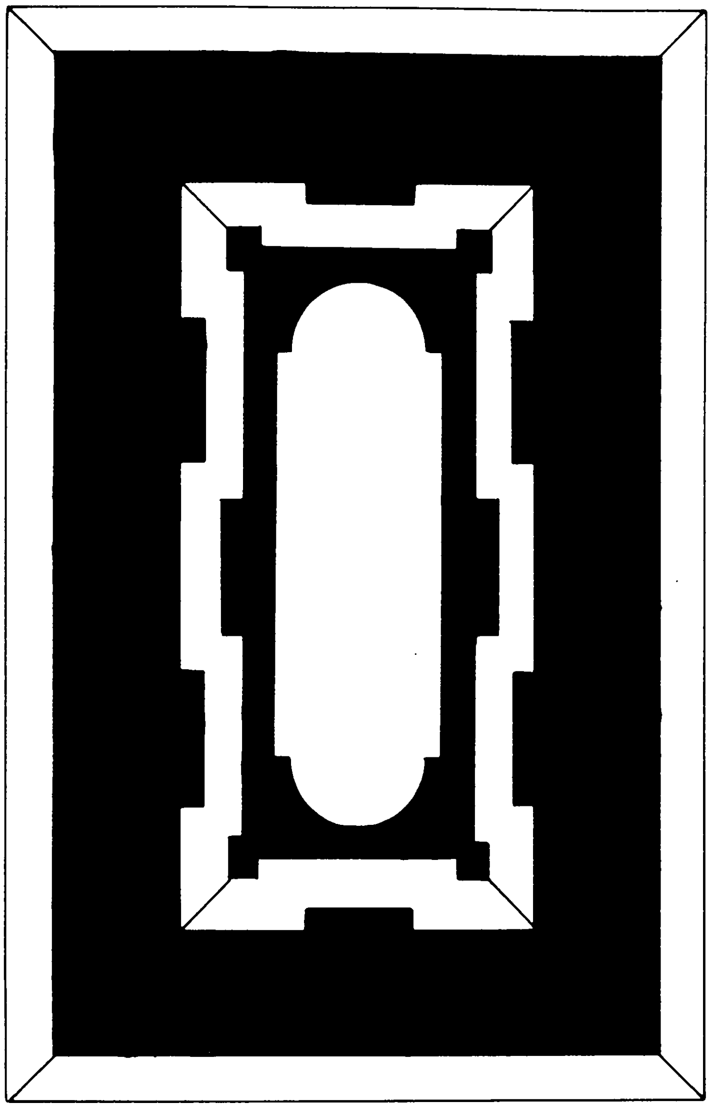


**Figure 7.5 Toolbox lid of the 1742a HH**

Design of ebony and ivory, with an ivory moulding around the edge.
Scale 1:1

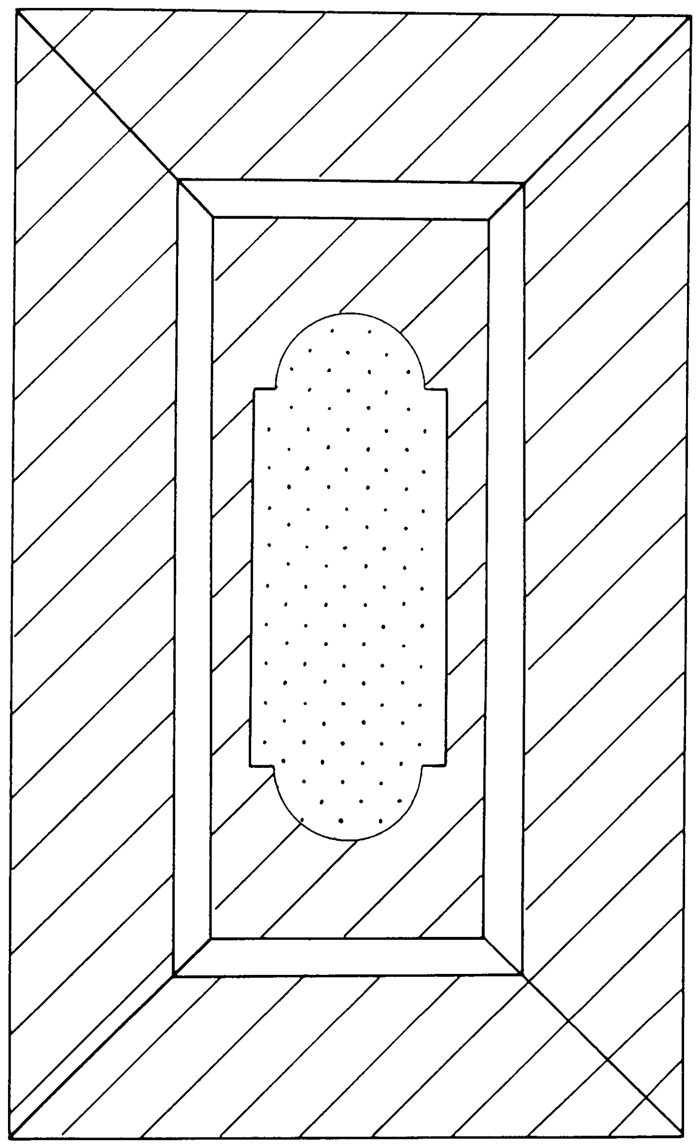


**Figure 7.6 Toolbox lid of the 1742b HH**

Design of walnut with a tortoise-shell centre.
The plateau is edged with ivory.
Scale 1:1

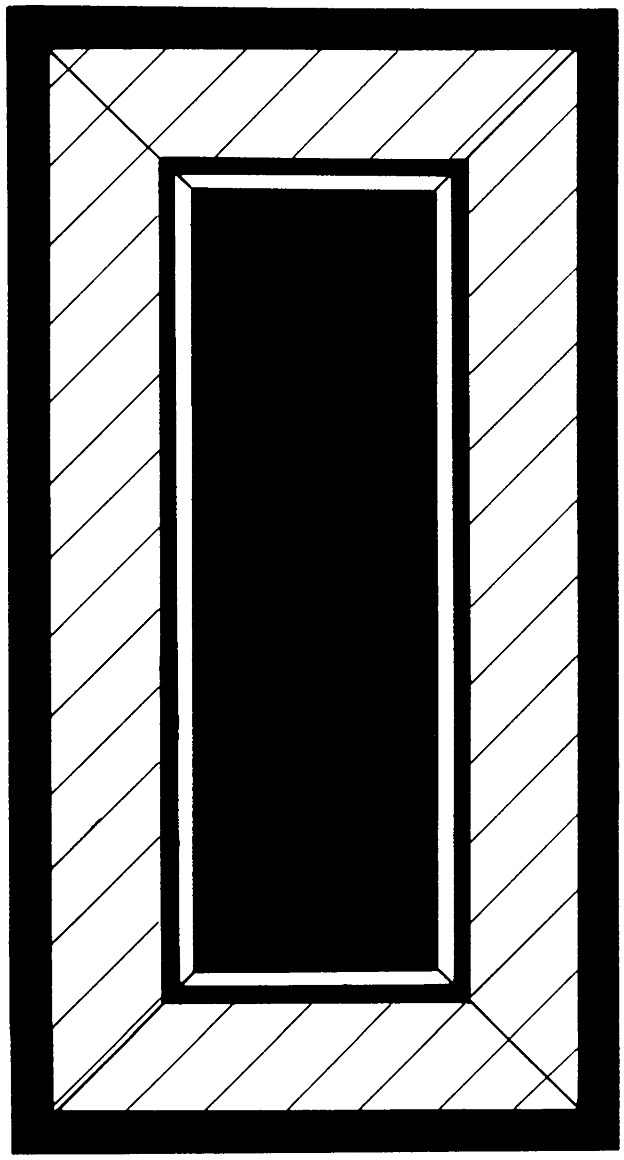


**Figure 7.7 Toolbox lid of the 1755 JH**

Design of walnut, ebony and ivory, with an ebony moulding around the edge.
Scale 1:1

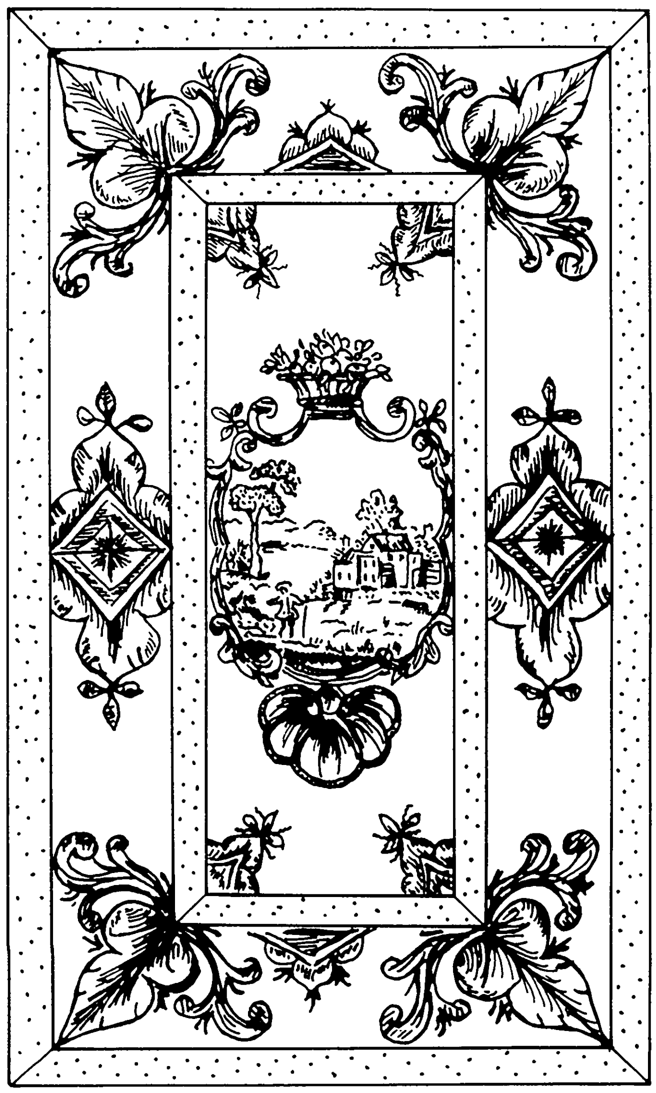


**Figure 7.8 Toolbox lid of the 1763a JH**

Design of engraved mother-of-pearl with a tortoise-shell moulding
around the edge and the central plateau.
Scale 1:1
Drawn by Jenny Nex

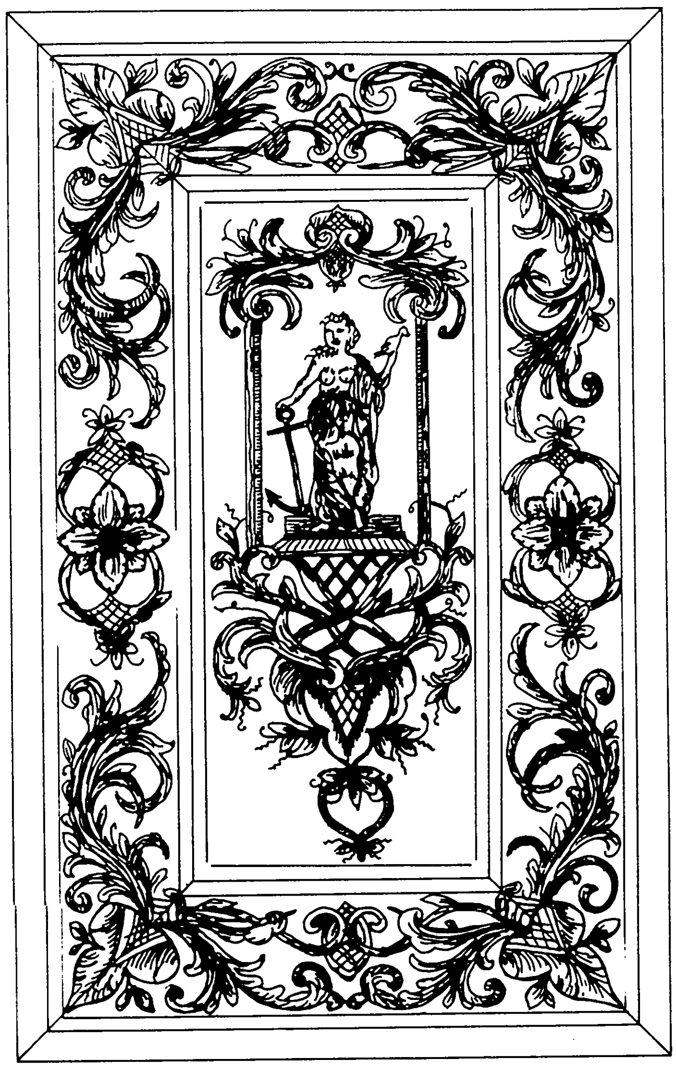


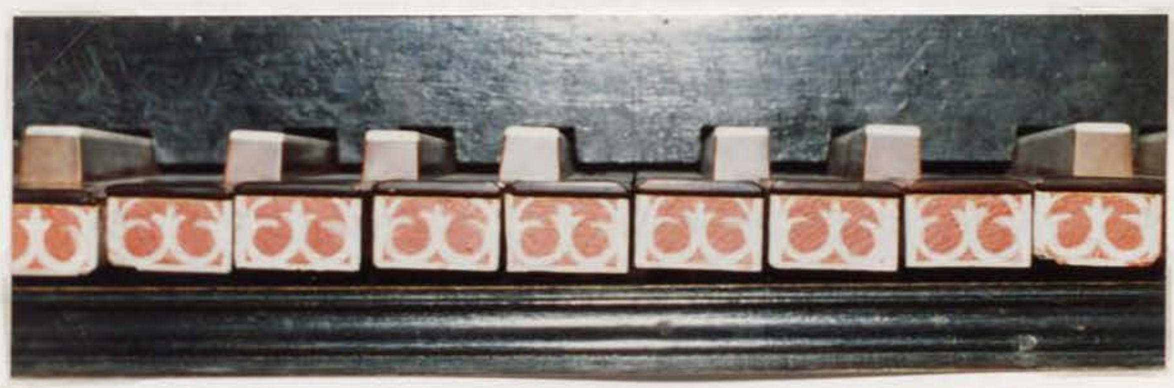
**Figure 7.9 Toolbox lid of the 1767 JH**

Design of engraved tortoise-shell and ivory,
with an ivory moulding around the edge.
Scale 1:1
Drawn by Jenny Nex

**THE KEYLEVERS**

The top surface of the natural keylevers is always roof-carved. The top surface of the sharp levers of Hieronymus Hass and early Johann Hass clavichords is carved in a waveform pattern, while the top surface of the sharp levers of late Johann Hass clavichords is roof-carved like the natural levers (for an illustration see chapter 4, p.126). The natural plates are usually made from ivory, although tortoise-shell is also used. All natural plates are decorated with four scribed lines, but only those lines incised into ivory plates are filled with a red pigment. Since the red pigment used to fill the scribed lines of the 1756 JG was found to be vermilion,[24] it is likely that this is also the pigment found in the scribed lines of Hass instruments. Hass uses two main types of arcade to decorate the front of the natural keylevers: a simple incised trefoil pattern in parchment or paper on a red paper ground (see plate 7.16); or, and more frequently, a small piece of ebony or ivory into which a semi-circular moulding has been cut (see plate 7.17).

**Plate 7.16**
**The paper arcades of the 1723 HH**

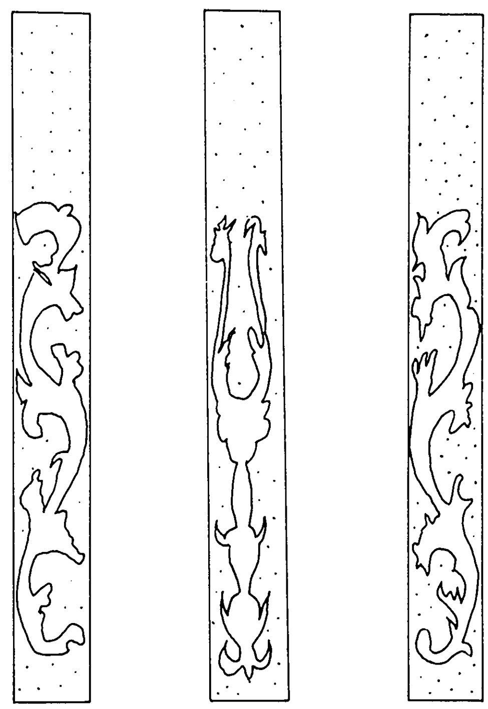


[24] G. O'Brien, "Investigative Analysis of the Unfretted Clavichord by I.C. Gerlach, Hamburg, 1756," held at Ringve Museum, Trondheim, with copies at the Russell Collection (Edinburgh, 1990), pp.10-11.

**Plate 7.17**
**The ivory arcades of the 1763a JH**

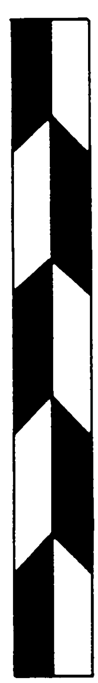
The accidental blocks of most Hass clavichords are topped with a thin veneer of ebony. As well as ebony, however, Hass occasionally used either tortoise-shell or mother-of-pearl as accidental veneer. Four clavichords, the 1742a HH, the 1744a HH, the 1744b HH and the 1748 JH make use of tortoise-shell, and the accidental blocks of the 1763a JH are capped with white mother-of-pearl. Mother-of-pearl is also the material Hass uses to veneer the accidental blocks of the 1740a HH. In this case, however, the veneer is also engraved (see figure 7.10). In addition to using single plates of ebony, tortoise-shell or mother-of-pearl Hass also makes use of two contrasting materials arranged in a chevron pattern. The accidental plates of the 1743a HH, the 1746 JH and the 1761b JH, for example, consist of a chevron pattern of ebony and ivory. The chevron-patterned accidental plates of the 1728 HH are made from tortoise-shell and ivory, and those of the 1767 JH are constructed from tortoise-shell and mother-of-pearl.

**Figure 7.10 Special accidental plates**
Scale 1:1



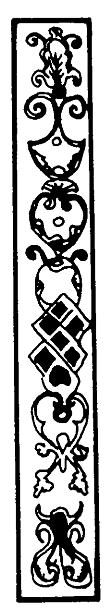
$f^{\#}$ $g^{\#}$ $b^{b}$

Accidental plates of the 1755 JH
Design of tortoise-shell with ivory inlay



Accidental plates of the 1743a HH

This chevron design of ebony and ivory
is also used for the 1746 JH and the 1761b JH



Accidental plates of the 1740a HH

Engraved mother-of-pearl

## CONCLUSION

It is probable that neither member of the Hass family would have undertaken the actual painting of his instruments since this would have brought them into conflict with one of the painters' guilds. The parquetry on the toolbox lid may too have been made by craftsmen specialising in this type of work. The similarity in the foliate design of the toolbox lids of the 1763a JH and the 1767 JH, for instance, suggest that they were engraved by the same person. It should also be noted that there is no apparent difference between the decoration of C to $d^3$ and FF to $f^3$ instruments. The amount of decoration depends upon the taste and wealth of the potential buyer and not necessarily upon the model. The C to $d^3$ 1740a HH is, for example, one of the most beautifully decorated of all Hass instruments.

Elements in the decoration of Hass instruments are also to be found on the harpsichords and clavichords of other makers. The same style of key arcade and strapwork hinge found on instruments made in the Hass workshops are, for example, also to be found on the clavichords of the Hamburg-maker Johann Gerlach, as well as the clavichord made in 1770 in Copenhagen by Moritz Moshack. This probably indicates that Hass, Gerlach and Moshack bought their key arcades and hinges from common suppliers. In addition to the arcades and the hinges the clavichords of these three makers have many other features in common as well, indicating that they were part of the same tradition of clavichord building.

# Chapter 8

# HASS IN THE CONTEXT OF THE NORTH-GERMANIC TRADITION OF CLAVICHORD BUILDING

## INTRODUCTION

Partly due to the relatively large number of surviving examples, the instruments of Hieronymus and Johann Hass dominate the history of eighteenth-century clavichords in the German-speaking regions of Western Europe. It is important to stress, however, that their clavichords have characteristics similar to other instruments made within the sphere of influence of Hamburg and in Scandinavia. The few surviving clavichords of Johann Gerlach of Hamburg and of Barthold Fritz of Brunswick, for example, display many of the characteristics, which I have detailed in previous chapters, of the clavichords of Hass. A number of Scandinavian clavichords, especially those built before about 1740, also have a number of Hass-like features. I have chosen to call this tradition, of which the instruments of Hass are part, the North-Germanic tradition of clavichord building. And I propose to show that clavichord makers resident in Hamburg, Brunswick, Copenhagen and Stockholm were all part of this North-Germanic tradition of clavichord building.

## HASS AND THE HAMBURG SCHOOL OF CLAVICHORD BUILDING

That an interchange of ideas took place within the walls of Hamburg there is no doubt, as there are several discernable characteristics which delineate instruments manufactured in this city. Harpsichords by Christian Zell, by the brothers Johann (II) and Carl Fleischer, as well as those by Hass, for example, have double-curved bentsides. The clavichords built by members of the Hamburg School usually have the following features in common: a) the use of Scots pine for the baseboard, the case sides, and the lid, b) a baseboard constructed from two planks of pine butt-jointed together along their length, c) the use of corner dovetail joints, d) mouldings cut directly into the baseboard and into the top edge of the case sides, e) a set of 4ft strings in the bass, f) a $c^2$ scaling of one Hamburg Fuss (286.49mm), and g) an elaborately-decorated toolbox lid. The similarity of instruments made by different builders resident in Hamburg must indicate that there was close contact between them. Indeed, master-apprentice relationships probably existed between Johann Fleischer I and Johann Middelburg, between Carl Fleischer and Christian Zell, between Hieronymus Hass and Johann Gerlach, and between Johann Hass and Johann Krogmann. Families inter-married, and at least three makers (Christian Zell, Johann Gerlach and Johann Hass) lived either in or close to the Gänsemarkt, where the opera house then stood.

**Johann Gerlach (ca. 1720-ca. 1795)**

Three clavichords, dated 1756, 1769 and 1780, are known to survive by the Hamburg maker Johann Christian Gerlach. All three clavichords are unfretted five-octave FF to $f^3$ instruments, with a set of 4ft strings in the bass. The many similarities between the two earliest surviving clavichords of Gerlach and those of the Hass family indicates not merely that Gerlach was working in the same tradition as Hass, but that he may in fact have been apprenticed to either Hieronymus or Johann.

The first to compare the materials and constructional procedures of Johann Gerlach with those of the Hass family was Grant O'Brien,[1] who noted that the 1756 JG had many features in common with the 1763a JH. Both Gerlach clavichords examined by the author, the 1756 JG and the 1769 JG, are constructed from the same wood types as those used by the Hass family: Scots pine is used for the case sides, the lid and the baseboard, oak for the tolbox lid, beech and pine for the

[1] G. O'Brien, "Catalogue Description: Unfretted Clavichord by I.C. Gerlach, Hamburg, 1756," held at Ringve Museum, Trondheim, with copies at the Russell Collection (Edinburgh, 1990), p.33.

balance rail, and lime for the keylevers. The 1756 JG and the 1769 JG also have the same soundboard layout, 8ft-bridge shape and string scalings as the five-octave FF to $f^3$ clavichords of Hass. The string scalings of the 1769 JG are, for example, virtually identical to the string scalings of the 1742a HH. As table 8.1 shows, not only are the 8ft scalings of both instruments based on a $c^2$ scaling of 12 Hamburg Zolle, but the degree of foreshortening below about the note $c^1$ is also the same. In this instance, for example, it is clear that both Gerlach and Hass intended the note FF to have a scaling of 60½ Zolle (nominally 1444.4mm, actual average 1446mm).

**Table 8.1**
**The string scalings of the 1742a HH and the 1769 JG**

| **1742a HH** | | | | **1769 JG** | | | |
|---|---|---|---|---|---|---|---|
| 8ft Strings | | 4ft Strings | | 8ft Strings | | 4ft Strings | |
| $f^3$ | 105 | | | $f^3$ | 104 | | |
| $c^3$ | 141 | | | $c^3$ | 142 | | |
| $f^2$ | 213 | | | $f^2$ | 212 | | |
| $c^2$ | 284 | | | $c^2$ | 284 | | |
| $f^1$ | 426 | | | $f^1$ | 431 | | |
| $c^1$ | 570 | | | $c^1$ | 572 | | |
| f | 813 | d | 572 | f | 822 | | |
| c | 986 | c | 616½ | c | 1008 | c | 620 |
| F | 1189 | F | 777 | F | 1200 | F | 785 |
| C | 1304 | C | 900 | C | 1310 | C | 910 |
| FF | 1445 | FF | 1080 | FF | 1447 | FF | 1088 |

The similarities between the clavichords of Hass and Gerlach suggest that Gerlach may have been apprenticed to one of the Hass family, probably Hieronymus Hass. This is a distinct possibility because, as table 8.2 shows, both the 1756 JG and the 1769 JG have virtually identical case dimensions as the two Hieronymus Hass clavichords dating from 1743. In the following year, 1744, Gerlach became a burgher of Hamburg, presumably having just completed his apprenticeship and paid the appropriate fees to the town council.[2] There is, however, no written evidence to support my belief that Gerlach was apprenticed to Hass, and no circumstantial evidence in the form of a marriage contract between the two families, since Gerlach did not marry either Hass's widow or daughter as was so often the case with apprentices.[3]

**Table 8.2**

**A comparison of the case dimensions of the two 1743 Hieronymus Hass clavichords with those built in 1756 and 1769 by Johann Gerlach**

| | Hieronymus Hass | | Johann Gerlach | |
|---|---|---|---|---|
| | 1743a HH | 1743b HH | 1756 JG | 1769 JG |
| Case length (without mouldings) | 1702 | 1700 | 1700½ | 1701 |
| Case length (with mouldings) | 1725 | 1727 | 1726 | 1726 |
| Inside case length | 1673 | 1667½ | 1670 | 1669 |
| Right-hand case front | 729 | 728 | 733 | 744 |
| Keywell length | 842 | 841½ | 844 | 840 |
| Width (without moulding) | 521 | 519 | 523½ | 517 |
| Width (with mouldings) | 539 | 546 | 535 | 535 |
| Inside width | 489 | 491 | 493 | 486½ |
| Height of case sides (without baseboard) | 132 | 138 | 133 | 133 |

Johann Gerlach must also have had some contact with Johann Hass, since differences between the 1756 JG and the 1769 JG appear to mirror evolutionary developments in the clavichords of this maker. For instance although the accidental keylevers of the 1756 JG are carved in a waveform pattern (like all the clavichords of the Hass family up until and including the 1748 JH), the accidental keylevers of the 1769 JG are, like most Johann Hass clavichords, roof-carved in the same manner as the natural keylevers. Johann Gerlach also appears to have made the same changes to the compass of the 4ft strings as Johann Hass, reducing the number of 4ft strings from twenty-two (FF to d on the 1756 JG) to twenty (FF to c on the 1769 JG).

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[2] D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.50.

[3] For example Söderström married Lindholm's daughter, Pascal Taskin married the widow of François-Étienne Blanchet II, and Christian Zell marrried the widow of Carl Fleischer.

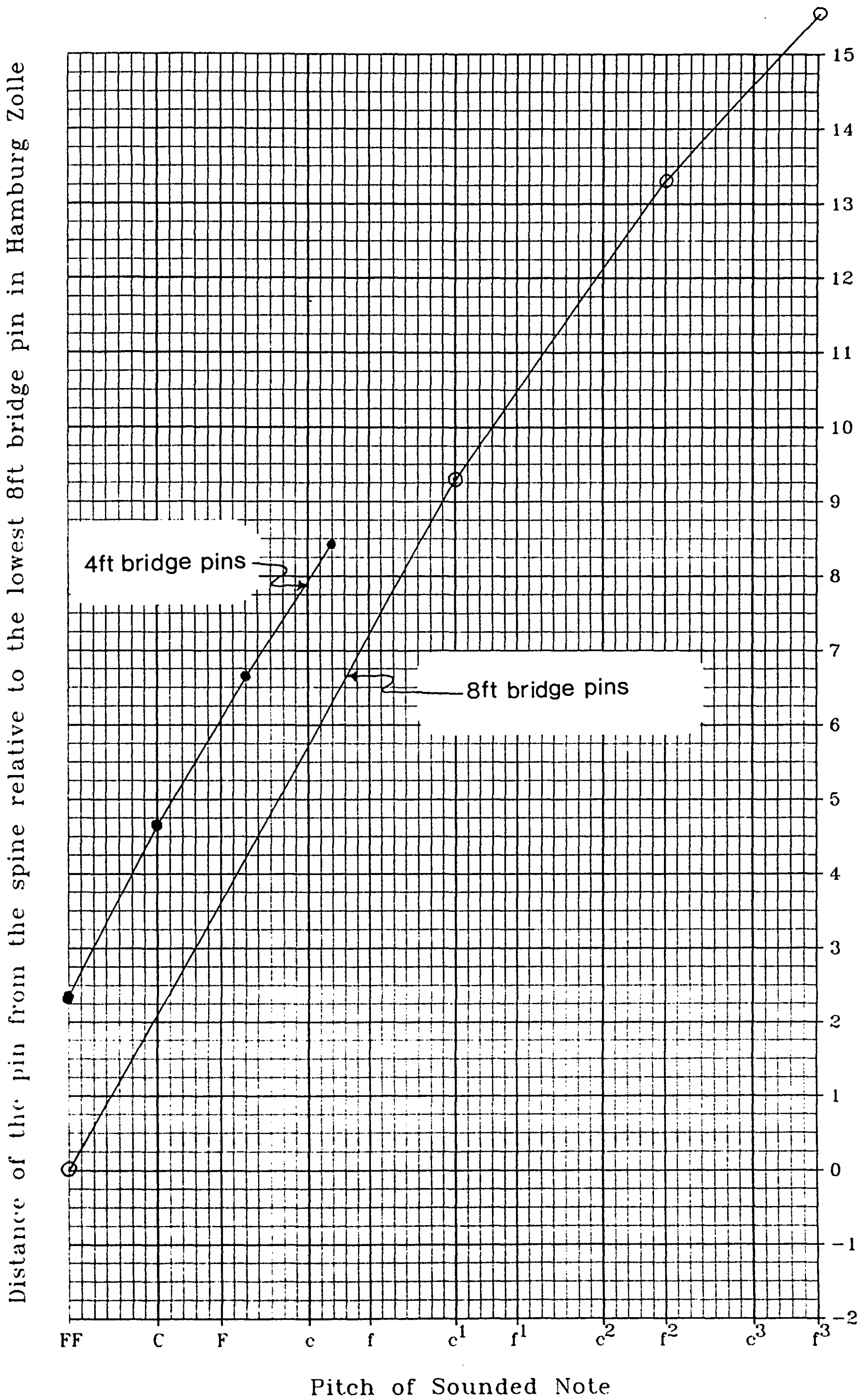
Before the year 1761 the 4ft stringing of all Hass clavichords is taken up to the note d, and after that date the 4ft stringing is taken up to either the note c or the note B.

Moreover, it is very likely that Gerlach used the same marking-out method as that which I have determined for Hass. My research has shown that Gerlach, like Hass, used notched sticks to mark out the position of the 8ft and the 4ft bridge pins on the bridges. The pin positions were marked out by holding the sticks at right-angles to the spine as the different sticks were moved across the soundboard area. The procedure used to determine Gerlach's method of marking out the position of the 8ft and the 4ft bridge pins is the same as that used for determining Hass's method of marking out. The distance of each 4ft bridge pin and each near pin of a pair of 8ft bridge pins was measured using the same technique as described in chapter 6, pp.172-3. Table 8.3a shows the distance of the bridge pins of the 1756 JG, the 1769 JG and the 1743b HH when measured at right-angles to the spine. The bridge-pin measurements were then plotted with the origin moved from the spine to the position of the lowest note (see graphs 8.1 and 8.2 for bridge-pin plots of the 1756 JG and of the 1769 JG respectively). As with the clavichords of Hass, the changes in the slope of the line joining the plotted points indicates that the lateral spacing of the 4ft bridge pins, and of the pairs of 8ft bridge pins of the two Gerlach clavichords, varies over the compass. The length of each linear segment can either be expressed in integral numbers of Hamburg Zolle, or integral numbers plus divisions of a half, a quarter, a third, or a tenth of the Hamburg Zolle. As has been shown in chapter 6, pp.174-8, dividing the length of the segment by the number of intervals between the 4ft bridge pins or the number of intervals between successive pairs of 8ft bridge pins, the lateral string spacing can be found (see table 8.3b). This turns out to be a regular division of whole numbers of the Hamburg Zolle, such as 10 in 3, 7 in 2, or 4 in 1 (see table 8.3c).

**Table 8.3a**
**Distance of the bridge pins from the spine of the 1743b HH, the 1756 JG and the 1769 JG**

| | 1743b HH | | 1756 JG | | 1769 JG | |
|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $f^3$ | 34 | | 33 | | 36½ | |
| $e^3$ | 37 | | 37 | | 40 | |
| $e^{b3}$ | 41 | | 41 | | 43½ | |
| $d^3$ | 45 | | 45 | | 47 | |
| $c^{\#3}$ | 49 | | 48½ | | 50½ | |
| $c^3$ | 54 | | 52½ | | 54 | |
| $b^2$ | 58 | | 57½ | | 58 | |
| $b^{b2}$ | 63 | | 62 | | 61 | |
| $a^2$ | 68 | | 67 | | 65 | |
| $g^{\#2}$ | 72 | | 72 | | 69 | |
| $g^2$ | 77 | | 76½ | | 72½ | |
| $f^{\#2}$ | 82 | | 81½ | | 77 | |
| $f^2$ | 87 | | 86 | | 81 | |
| $e^2$ | 92 | | 91 | | 85 | |
| $e^{b2}$ | 96 | | 96 | | 90 | |
| $d^2$ | 101 | | 101 | | 94 | |
| $c^{\#2}$ | 106 | | 105½ | | 98½ | |
| $c^2$ | 111 | | 111 | | 103 | |
| $b^1$ | 116 | | 115½ | | 107½ | |
| $b^{b1}$ | 121 | | 121½ | | 112 | |
| $a^1$ | 126 | | 127 | | 117 | |
| $g^{\#1}$ | 131 | | 133 | | 122 | |
| $g^1$ | 136½ | | 138 | | 127 | |
| $f^{\#1}$ | 142 | | 143 | | 132½ | |
| $f^1$ | 147 | | 150 | | 138 | |
| $e^1$ | 153 | | 156 | | 143½ | |
| $e^{b1}$ | 160 | | 162 | | 149 | |
| $d^1$ | 166 | | 168 | | 155 | |
| $c^{\#1}$ | 173 | | 174 | | 161 | |
| $c^1$ | 179 | | 181 | | 167 | |
| b | 185½ | | 188 | | 173½ | |
| $b^b$ | 193 | | 195 | | 180 | |
| a | 200 | | 202 | | 187 | |
| $g^\#$ | 207½ | | 209 | | 194 | |
| g | 214 | | 216 | | 201 | |
| $f^\#$ | 222 | | 223½ | | 209 | |
| f | 229 | | 231 | | 217 | |
| e | 237 | | 238 | | 224½ | |
| $e^b$ | 244 | | 245 | | 232½ | |
| d | 252 | 198½ | 254 | 201 | 241 | |
| $c^\#$ | 259 | 204 | 261½ | 207 | 249 | |
| c | 266 | 209 | 268 | 213 | 259 | 206 |
| B | 273 | 215 | 275 | 218 | 266 | 212 |
| $B^b$ | 281 | 221 | 282½ | 223½ | 273 | 218½ |
| A | 287½ | 227 | 290 | 231 | 280 | 225 |
| $G^\#$ | 295 | 234 | 296½ | 237½ | 287 | 231 |
| G | 301½ | 240 | 304 | 244 | 294 | 238 |
| $F^\#$ | 309 | 247 | 311½ | 251 | 301½ | 245 |
| F | 316 | 254 | 318½ | 259 | 309 | 251½ |
| E | 322½ | 260½ | 325½ | 265½ | 316½ | 259 |
| $E^b$ | 330½ | 267 | 333 | 273½ | 323½ | 266 |
| D | 337 | 275 | 340 | 281 | 330½ | 274 |
| $C^\#$ | 344 | 283 | 347½ | 288 | 338 | 281½ |
| C | 352 | 289½ | 355 | 296 | 345 | 289 |
| BB | 358½ | 297½ | 362 | 304 | 353 | 297 |
| $BB^b$ | 365 | 305½ | 370 | 311 | 360 | 305 |
| AA | 372 | 313 | 377 | 320 | 367 | 312 |
| $GG^\#$ | 379 | 320½ | 384½ | 327 | 375 | 320½ |
| GG | 387 | 328 | 392 | 336 | 382 | 329 |
| $FF^\#$ | 393½ | 337 | 400 | 345 | 390 | 336 |
| FF | 401 | 345 | 408½ | 353½ | 397 | 344½ |

**Graph 8.1**
**Bridge pin positions of the 1756 JG**



**Graph 8.2**
**Bridge pin positions of the 1769 JG**

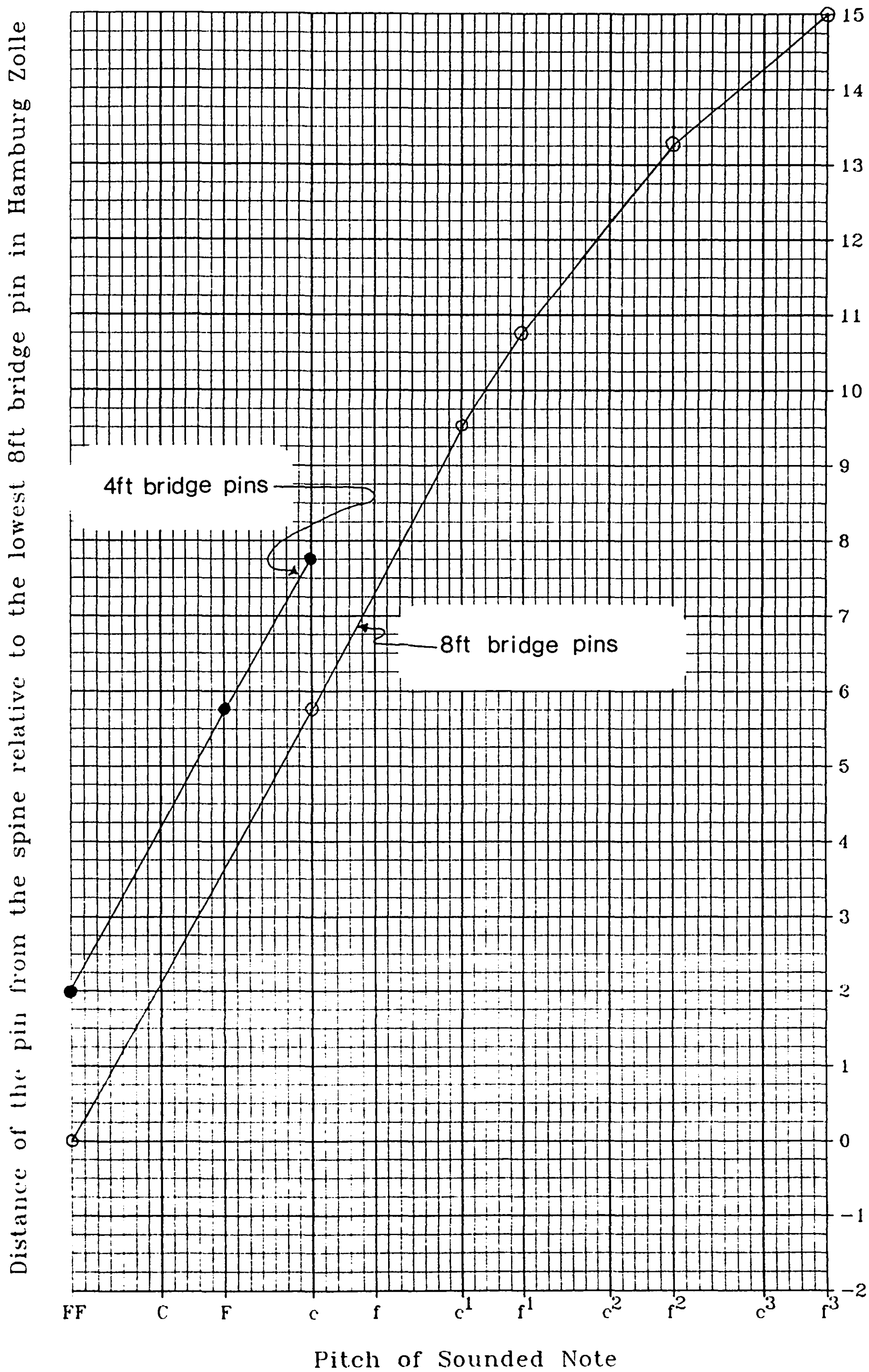


**Table 8.3b**
**Number of string pairs per Zoll for the 1743b HH, the 1756 JG and the 1769 JG**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1743b HH 8ft | 1743b HH 4ft | 1756 JG 8ft | 1756 JG 4ft | 1769 JG 8ft | 1769 JG 4ft |
|---|---|---|---|---|---|---|
| $f^3$ | 12 in $2\frac{1}{4}$ | | 12 in $2\frac{1}{4}$ | | 12 in $1^4/_5$ | |
| $e^3$ | | | | | | |
| $e^{b3}$ | | | | | | |
| $d^3$ | | | | | | |
| $c^{\#3}$ | | | | | | |
| $c^3$ | | | | | | |
| $b^2$ | | | | | | |
| $b^{b2}$ | | | | | | |
| $a^2$ | | | | | | |
| $g^{\#2}$ | | | | | | |
| $g^2$ | | | | | | |
| $f^{\#2}$ | 12 in $2\frac{1}{4}$ | | 12 in $2\frac{1}{4}$ | | 12 in $1^4/_5$ | |
| $f^2$ | 12 in $2\frac{1}{2}$ | | 17 in 4 | | 12 in $2\frac{1}{2}$ | |
| $e^2$ | | | | | | |
| $e^{b2}$ | | | | | | |
| $d^2$ | | | | | | |
| $c^{\#2}$ | | | | | | |
| $c^2$ | | | | | | |
| $b^1$ | | | | | | |
| $b^{b1}$ | | | | | | |
| $a^1$ | | | | | | |
| $g^{\#1}$ | | | | | | |
| $g^1$ | | | | | | |
| $f^{\#1}$ | 12 in $2\frac{1}{2}$ | | | | 12 in $2\frac{1}{2}$ | |
| $f^1$ | 12 in $3^1/_3$ | | | | 5 in $1\frac{1}{4}$ | |
| $e^1$ | | | | | | |
| $e^{b1}$ | | | | | | |
| $d^1$ | | | | | | |
| $c^{\#1}$ | | | 17 in 4 | | 5 in $1\frac{1}{4}$ | |
| $c^1$ | | | 31 in $9^3/_{10}$ | | 12 in $3^3/_4$ | |
| b | | | | | | |
| $b^b$ | | | | | | |
| a | | | | | | |
| $g^\#$ | | | | | | |
| g | | | | | | |
| $f^\#$ | 12 in $3^1/_3$ | | | | | |
| f | 24 in 7 | | | | | |
| e | | | | | | |
| $e^b$ | | | | | | |
| d | | 9 in $2\frac{1}{4}$ | | 7 in $1^3/_4$ | | |
| $c^\#$ | | | | | 12 in $3^3/_4$ | |
| c | | | | | 19 in $5^7/_{10}$ | 7 in 2 |
| B | | | | | | |
| $B^b$ | | | | | | |
| A | | | | | | |
| $G^\#$ | | | | 7 in $1^3/_4$ | | |
| G | | | | 7 in 2 | | |
| $F^\#$ | | 9 in $2\frac{1}{4}$ | | | | 7 in 2 |
| F | | 12 in $3^3/_4$ | | | | 12 in $3^3/_4$ |
| E | | | | | | |
| $E^b$ | | | | | | |
| D | | | | | | |
| $C^\#$ | | | | 7 in 2 | | |
| C | | | | 7 in $2^1/_3$ | | |
| BB | | | | | | |
| $BB^b$ | | | | | | |
| AA | | | | | | |
| $GG^\#$ | | | | | | |
| GG | | | | | | |
| $FF^\#$ | | | | | | |
| FF | 24 in 7 | 12 in $3^3/_4$ | 31 in $9^3/_{10}$ | 7 in $2^1/_3$ | 19 in $5^7/_{10}$ | 12 in $3^3/_4$ |

**Table 8.3c**
**Marking-out stick divisions for the 1743b HH, the 1756 JG and the 1769 JG**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | **1743b HH** | | **1756 JG** | | **1769 JG** | |
|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $f^3$ | 16 in 3 | | 16 in 3 | | 20 in 3 | |
| $e^3$ | | | | | | |
| $e^{b3}$ | | | | | | |
| $d^3$ | | | | | | |
| $c^{\#3}$ | | | | | | |
| $c^3$ | | | | | | |
| $b^2$ | | | | | | |
| $b^{b2}$ | | | | | | |
| $a^2$ | | | | | | |
| $g^{\#2}$ | | | | | | |
| $g^2$ | | | | | | |
| $f^{\#2}$ | 16 in 3 | | 16 in 3 | | 20 in 3 | |
| $f^2$ | 24 in 5 | | 17 in 4 | | 24 in 5 | |
| $e^2$ | | | | | | |
| $e^{b2}$ | | | | | | |
| $d^2$ | | | | | | |
| $c^{\#2}$ | | | | | | |
| $c^2$ | | | | | | |
| $b^1$ | | | | | | |
| $b^{b1}$ | | | | | | |
| $a^1$ | | | | | | |
| $g^{\#1}$ | | | | | | |
| $g^1$ | | | | | | |
| $f^{\#1}$ | 24 in 5 | | | | 24 in 5 | |
| $f^1$ | 18 in 5 | | | | 4 in 1 | |
| $e^1$ | | | | | | |
| $e^{b1}$ | | | | | | |
| $d^1$ | | | | | | |
| $c^{\#1}$ | | | 17 in 4 | | 4 in 1 | |
| $c^1$ | | | 10 in 3 | | 16 in 5 | |
| b | | | | | | |
| $b^b$ | | | | | | |
| a | | | | | | |
| $g^\#$ | | | | | | |
| g | | | | | | |
| $f^\#$ | 18 in 5 | | | | | |
| f | 24 in 7 | | | | | |
| e | | | | | | |
| $e^b$ | | | | | | |
| d | | 4 in 1 | | 4 in 1 | | |
| $c^\#$ | | | | | 16 in 5 | |
| c | | | | | 10 in 3 | 7 in 2 |
| B | | | | | | |
| $B^b$ | | | | | | |
| A | | | | | | |
| $G^\#$ | | | | 4 in 1 | | |
| G | | | | 7 in 2 | | |
| $F^\#$ | | 4 in 1 | | | | 7 in 2 |
| F | | 16 in 5 | | | | 16 in 5 |
| E | | | | | | |
| $E^b$ | | | | | | |
| D | | | | | | |
| $C^\#$ | | | | 7 in 2 | | |
| C | | | | 3 in 1 | | |
| BB | | | | | | |
| $BB^b$ | | | | | | |
| AA | | | | | | |
| $GG^\#$ | | | | | | |
| GG | | | | | | |
| $FF^\#$ | | | | | | |
| FF | 24 in 7 | 16 in 5 | 10 in 3 | 3 in 1 | 10 in 3 | 16 in 5 |

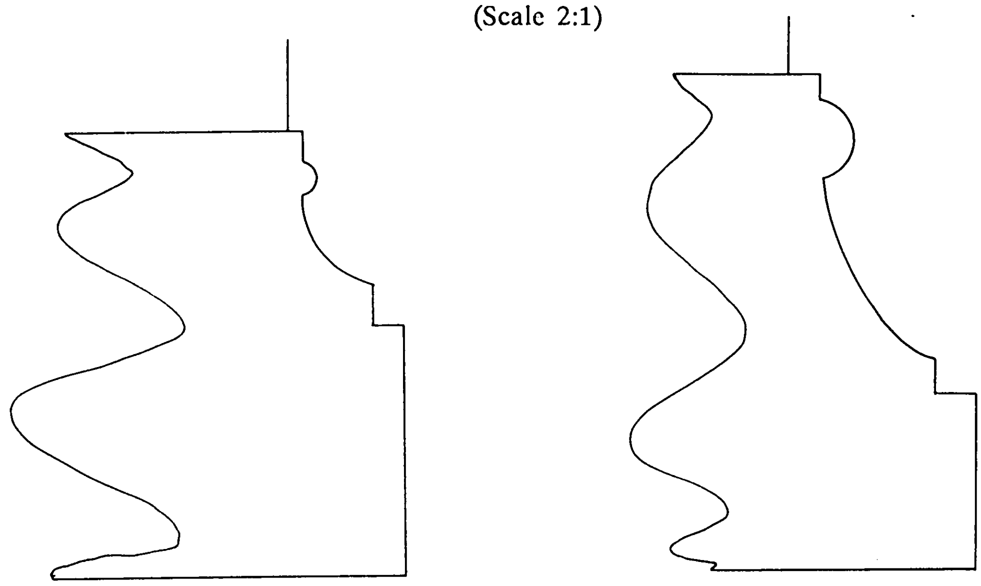
It is clear from this analysis that Gerlach did not use exactly the same sticks as Hass in the marking-out of the position of the bridge pins, but he did use the same method. It is interesting to note, however, that the 1756 JG has the same lateral string spacing as the 1743b HH from $f^2$ to $f^3$, and that the 1769 JG has the same lateral string spacing as the 1743b HH from $f^1$ to $f^2$. The lateral spacing of the 4ft strings from FF to F is also the same for the 1769 JG and the 1743b HH.

Having shown that the two Gerlach clavichords have much in common with the clavichords of the Hass family, it is also necessary to point out the differences between the two makers. The baseboard moulding of Gerlach clavichords has, for example, the same elements as the moulding on the baseboard of Hass clavichords, but is much larger (see figure 8.1). Gerlach also used a different template from that used in the Hass workshops to mark out the corner dovetail joints of the clavichord case. Furthermore, the practice of Gerlach seems to have been to string the treble more heavily than Hass. Gerlach marks gauge 6 from $c^2$ to $f^3$, whereas Hass marks gauge 6 only from $c^2$ to $d^3$ and then the lighter gauge 7 from $e^{b3}$ to $f^3$ (see table 8.5). Another distinguishing feature of the two Gerlach clavichords is that the ends of the two balance cords are attached to the balance rail with an iron tack. The practice of the Hass family was to secure the ends of the balance cords with a wooden peg.

**Dietrich Hass (ca. 1731-ca. 1796)**

Dietrich Hass has long been considered the restorer of the five-octave FF to $f^3$ clavichord in the Museum für Kunst und Gewerbe in Hamburg, which bears his name together with the date 1796. It was Schröder who first suggested that this clavichord, inventory number 1904.709, was originally built by Johann Hass in the 1760s.[4] The clavichord has octave strings in the bass (from FF to d) and, as table 8.4 shows, the case dimensions of the 1796 DH are very similar to the case dimensions of the 1761c JH, the 1762 JH and the 1763a JH. The position of the 8ft bridge relative to the right-hand end of the case is also typical of clavichords built in the 1760's by Johann Hass.

**Figure 8.1**
**Hass and Gerlach moulding profiles in section**
(Scale 2:1)



Baseboard moulding of the 1743b HH    Baseboard moulding of the 1756 JG[5]

**Table 8.4**
**Johann Hass and Dietrich Hass case dimensions (in mm)**

| | JOHANN HASS | | | DIETRICH HASS |
|---|---|---|---|---|
| | 1761c JH | 1762 JH | 1763a JH | 1796 DH |
| Case length (without mouldings) | 1729 | 1736 | 1730 | 1732 |
| Inside case length | 1697 | 1701 | 1694 | 1705 |
| Right-hand case front | 763 | 765½ | 760 | 764 |
| Keywell length | 848 | 844 | 845 | 839 |
| Width (without moulding) | 534 | 536 | 535 | 535 |
| Inside width | 500 | 501 | 497½ | 508 |
| Height of case sides | 138 | 138 | 140 | 137 |

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[4] See D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.61.

[5] The baseboard moulding of the 1756 JG is taken from the technical drawing of that instrument made by Darryl Martin. Copyright, Ringve Museum, Trondheim, 1990.

**Table 8.5**
**Comparison of Hass, Gerlach and Lemme Gauge Markings**

| | **HAMBURG** | **HAMBURG** | | **BRUNSWICK** | |
|---|---|---|---|---|---|
| | **C to $d^3$** | **FF to $f^3$** | | **C to $f^3$** | |
| | H. Hass 1740 | H. & J. Hass 1743-1767 | J. Gerlach 1756-1769 | C. Lemme 1766 | |
| $f^3$ | | 7 | 6 | 7 | $f^3$ |
| $e^3$ | | | | | $e^3$ |
| $e^{b3}$ | | 7 | | | $e^{b3}$ |
| $d^3$ | 6 | 6 | | 7 | $d^3$ |
| $c^{\#3}$ | | | | 6 | $c^{\#3}$ |
| $c^3$ | | | | | $c^3$ |
| $b^2$ | | | | | $b^2$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^2$ | | | | | $a^2$ |
| $g^{\#2}$ | | | | | $g^{\#2}$ |
| $g^2$ | | | | | $g^2$ |
| $f^{\#2}$ | | | | | $f^{\#2}$ |
| $f^2$ | | | | | $f^2$ |
| $e^2$ | | | | | $e^2$ |
| $e^{b2}$ | | | | | $e^{b2}$ |
| $d^2$ | | | | | $d^2$ |
| $c^{\#2}$ | | | | | $c^{\#2}$ |
| $c^2$ | 6 | 6 | 6 | 6 | $c^2$ |
| $b^1$ | 5 | 5 | 5 | 5 | $b^1$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^1$ | | | | | $a^1$ |
| $g^{\#1}$ | | | | | $g^{\#1}$ |
| $g^1$ | | | | | $g^1$ |
| $f^{\#1}$ | | | | | $f^{\#1}$ |
| $f^1$ | | | | | $f^1$ |
| $e^1$ | | | | | $e^1$ |
| $e^{b1}$ | | | | | $e^{b1}$ |
| $d^1$ | | | | | $d^1$ |
| $c^{\#1}$ | | | | | $c^{\#1}$ |
| $c^1$ | | 5 | 5 | 5 | $c^1$ |
| b | | 4 | 4 | 4 | b |
| $b^b$ | 5 | | | | $b^b$ |
| a | 4 | | | | a |
| $g^\#$ | | | | | $g^\#$ |
| g | | | | | g |
| $f^\#$ | | | | | $f^\#$ |
| f | | 4 | 4 | 4 | f |
| e | | 3 | 3 | 3 | e |
| $e^b$ | 4 | | | | $e^b$ |
| d | 3 | | | | d |
| $c^\#$ | | | | | $c^\#$ |
| c | | | | | c |
| B | | | | 3 | B |
| $B^b$ | 3 | 3 | 3 | 2 | $B^b$ |
| A | 2 | 2 | 2 | | A |
| $G^\#$ | | | | | $G^\#$ |
| G | | | | 2 | G |
| $F^\#$ | 2 | 2 | 2 | ? | $F^\#$ |
| F | 1 | 1 | 1 | | F |
| E | | | | | E |
| $E^b$ | 1 | 1 | 1 | | $E^b$ |
| D | 0 | 0 | 0 | | D |
| $C^\#$ | | | | | $C^\#$ |
| C | 0 | | 0 | ? | C |
| BB | | 0 | 00 | | BB |
| $BB^b$ | | 00 | | | $BB^b$ |
| AA | | | | | AA |
| $GG^\#$ | | 00 | 00 | | $GG^\#$ |
| GG | | 000 | 000 | | GG |
| $FF^\#$ | | | | | $FF^\#$ |
| FF | | 000 | 000 | | FF |

However, the 1796 DH has many features typical of instruments built in the workshops of Hieronymus and Johann Hass during the 1740s rather than the 1760s. The accidental keylevers, for example, are meander-carved, whereas the accidental keylevers of all clavichords built by Johann Hass after 1748 are roof-carved. Atypical of the clavichords of either Hieronymus or Johann Hass is the fact that the 8ft bridge of the 1796 DH is back-pinned from FF to E. Because the diameter of the back pins is the same as the diameter of the bridge pins, and because the back pins have the same lateral spacing as the bridge pins it is unlikely that this is a later alteration. The 8ft bridge of only one clavichord by Hieronymus Hass, the 1742a HH, is back-pinned for the bottom twelve notes. Another aspect of the 1796 DH which is unlike the clavichords built by Johann Hass in the 1760s is the balance rail. The balance rail of the 1796 DH is constructed of two lengths of wood, one of beech and one of lime, glued on top of each other. In total there are eight clavichords by Hieronymus and Johann Hass, six of which date from the 1740s, which are constructed in this manner.

In addition, the 1796 DH has several individual features. The marking-out of the bridge pins, the hitchpins and the tuning pins, for example, is different from that of Hieronymus and Johann Hass (see tables 8.6a to 8.6c and graph 8.3). Also the relatively narrow keywell span of 839mm means that the three-octave span of 487½mm is atypical of their clavichords. Furthermore, the rack-slot spacing pattern and the 8ft-bridge shape are unique to this instrument. These important differences, plus the fact that the 1796 DH has features in common with Hieronymus and Johann Hass clavichords from both the 1740s and the 1760s suggests that Dietrich Hass was the original maker of this instrument. I believe that the similarities between the 1796 DH and the clavichords of both Hieronymus and Johann Hass are possibly a consequence of Dietrich Hass having served an apprenticeship with either father or son, or perhaps with Gerlach.

**Table 8.6a**
**Distance of the pins fron the spine of the 1796 DH**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 33 | | 794 | | | | |
| $e^3$ | 37 | 33½ | 775 | | | | |
| $e^{b3}$ | 40½ | | 756 | | | | |
| $d^3$ | 44 | 43½ | 737 | | | | |
| $c^{\#3}$ | 48 | | 717 | | | | |
| $c^3$ | 54 | 53 | 696 | | | | |
| $b^2$ | 57 | | 674½ | | | | |
| $b^{b2}$ | 61 | 63½ | 654 | | | | |
| $a^2$ | 66 | | 633 | | | | |
| $g^{\#2}$ | 71 | 73 | 612½ | | | | |
| $g^2$ | 75 | | 591 | | | | |
| $f^{\#2}$ | 80 | 83 | 570 | | | | |
| $f^2$ | 84½ | | 550 | | | | |
| $e^2$ | 89 | 92½ | 530 | | | | |
| $e^{b2}$ | 93 | | 508 | | | | |
| $d^2$ | 97½ | 103 | 487½ | | | | |
| $c^{\#2}$ | 102 | | 466 | | | | |
| $c^2$ | 107 | 113 | 445 | | | | |
| $b^1$ | 111½ | | 424 | | | | |
| $b^{b1}$ | 117 | 122 | 403½ | | | | |
| $a^1$ | 122 | | 383 | | | | |
| $g^{\#1}$ | 127½ | 133 | 362 | | | | |
| $g^1$ | 132½ | | 341 | | | | |
| $f^{\#1}$ | 137 | 143½ | 320 | | | | |
| $f^1$ | 142 | | 299 | | | | |
| $e^1$ | 147½ | 154 | 278 | | | | |
| $e^{b1}$ | 153½ | | 257½ | | | | |
| $d^1$ | 159 | 166 | 236½ | | | | |
| $c^{\#1}$ | 164 | | 215 | | | | |
| $c^1$ | 170 | 178½ | 194½ | | | | |
| b | 176½ | | 173½ | | | | |
| $b^b$ | 183 | 193 | 153 | | | | |
| a | 190 | | 132 | | | | |
| $g^\#$ | 197½ | 207 | 111 | | | | |
| g | 205 | | 90½ | | | | |
| $f^\#$ | 214 | 222 | 69 | | | | |
| f | 222 | | 48½ | | | | |
| e | 230 | 237 | | 51 | | | |
| $e^b$ | 238 | | | 56 | | | |
| d | 247 | 253½ | | 62 | 59 | 196 | 196½ |
| $c^\#$ | 255 | | | 67 | 65 | 202½ | 204 |
| c | 262 | 267 | | 72½ | 71 | 209 | 212 |
| B | 269 | | | 77½ | 75½ | 216 | 218½ |
| $B^b$ | 277 | 281 | | 83½ | 82 | 222 | 227 |
| A | 284 | 291 | | 88 | 86 | 230 | 233½ |
| $G^\#$ | 291½ | 299 | | 95 | 93 | 236 | 242 |
| G | 299 | 308 | | 100 | 99 | 244 | 249 |
| $F^\#$ | 306½ | 315 | | 107 | 104 | 251½ | 256 |
| F | 314 | 323 | | 113 | 111 | 258 | 264 |
| E | 322 | 334 | | 119 | 117 | 266 | 272 |
| $E^b$ | 329 | 341 | | 124½ | 122 | 274½ | 279 |
| D | 337½ | 348 | | 131 | 129 | 282 | 288 |
| $C^\#$ | 345 | 356 | | 137 | 134½ | 290 | 295 |
| C | 353 | 364 | | 143½ | 142 | 297½ | 304 |
| BB | 361 | 372 | | 149 | 147½ | 306 | 312 |
| $BB^b$ | 368 | 379 | | 156 | 156 | 314 | 319 |
| AA | 375½ | 387 | | 162½ | 161½ | 322½ | 329 |
| $GG^\#$ | 383½ | 394 | | 170 | 170 | 330 | 337 |
| GG | 391 | 404 | | 176 | 175½ | 339½ | 346 |
| $FF^\#$ | 398 | 412 | | 184 | 185 | 348 | 354½ |
| FF | 406 | 421 | | 191 | 189½ | 357 | 364½ |

**Graph 8.3**
**Bridge pin, hitchpin and tuning pin positions of the 1796 DH**

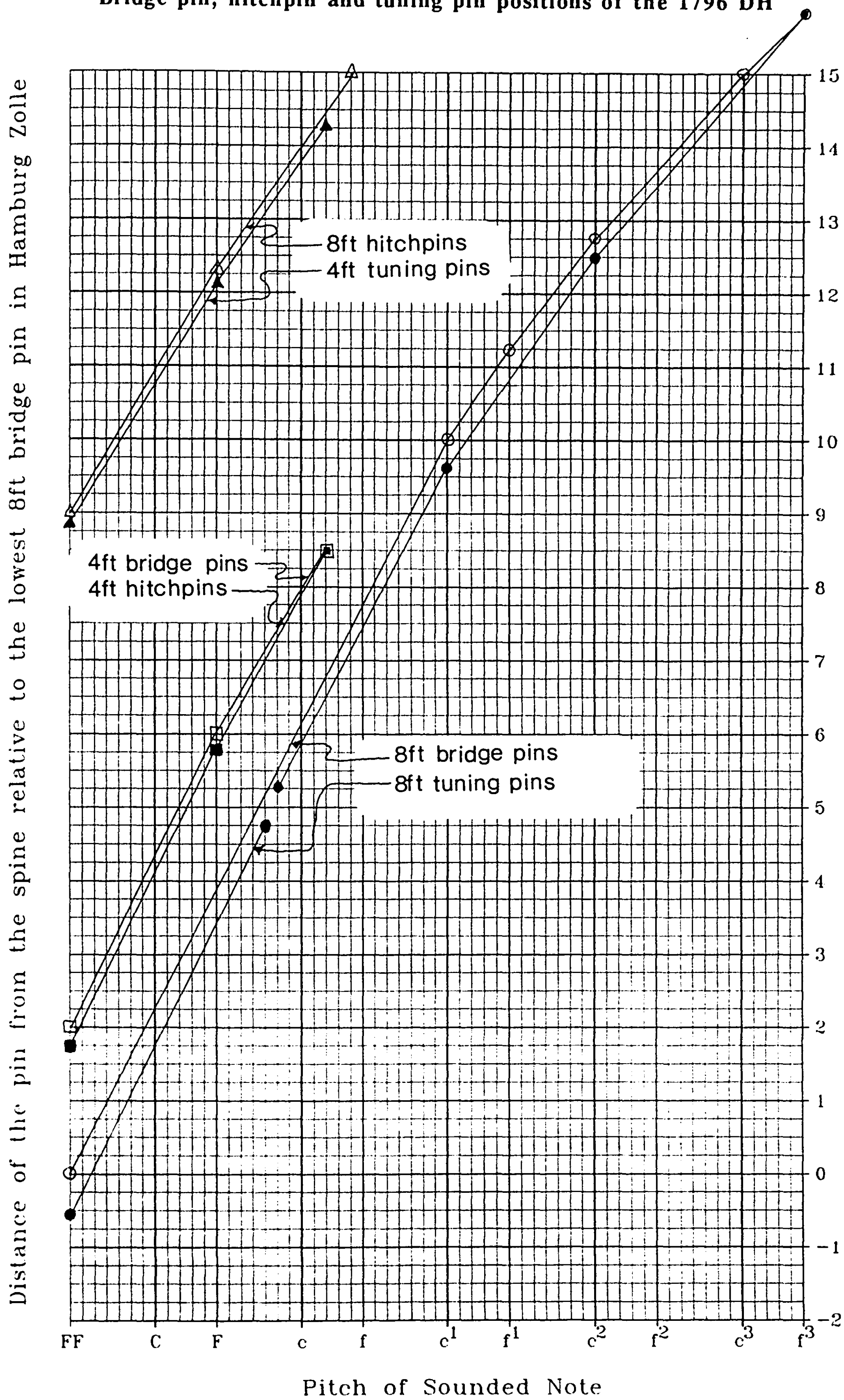

**Table 8.6b**
**Number of string pairs per Zoll for the 1796 DH**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 8FT | | | | 4FT | | |
|---|---|---|---|---|---|---|---|
| | BRIDGE PINS | TUNING PINS | TREBLE HITCHPINS | BASS HITCHPINS | TUNING PINS | BRIDGE PINS | HITCH PINS |
| $f^3$ | 5 in $\frac{5}{6}$ | 8 in $3\frac{1}{3}$ | 36 in $31\frac{1}{2}$ | | | | |
| $e^3$ | | | | | | | |
| $e^{b3}$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^{\#3}$ | 5 in $\frac{5}{6}$ | | | | | | |
| $c^3$ | 12 in $2\frac{1}{4}$ | | | | | | |
| $b^2$ | | | | | | | |
| $b^{b2}$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^{\#2}$ | | | | | | | |
| $g^2$ | | | | | | | |
| $f^{\#2}$ | | | | | | | |
| $f^2$ | | | | | | | |
| $e^2$ | | | | | | | |
| $e^{b2}$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^{\#2}$ | 12 in $2\frac{1}{4}$ | 8 in $3\frac{1}{3}$ | | | | | |
| $c^2$ | 7 in $1\frac{1}{2}$ | 6 in $2\frac{2}{3}$ | | | | | |
| $b^1$ | | | | | | | |
| $b^{b1}$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^{\#1}$ | | | | | | | |
| $g^1$ | | | | | | | |
| $f^{\#1}$ | 7 in $1\frac{1}{2}$ | | | | | | |
| $f^1$ | 5 in $1\frac{1}{4}$ | | | | | | |
| $e^1$ | | | | | | | |
| $e^{b1}$ | | | | | | | |
| $d^1$ | | | | | | | |
| $c^{\#1}$ | 5 in $1\frac{1}{4}$ | 6 in $2\frac{2}{3}$ | | | | | |
| $c^1$ | 31 in 10 | 7 in $4\frac{3}{8}$ | | | | | |
| b | | | | | | | |
| $b^b$ | | | | | | | |
| a | | | | | | | |
| $g^\#$ | | | | | | | |
| g | | | | | | | |
| $f^\#$ | | | | | | | |
| f | | | 36 in $31\frac{1}{2}$ | | | | |
| e | | | | 11 in $2\frac{3}{4}$ | | | |
| $e^b$ | | | | | | | |
| d | | | | | 9 in $2\frac{1}{4}$ | 9 in $2\frac{1}{2}$ | 9 in $2\frac{7}{10}$ |
| $c^\#$ | | | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | 7 in $4\frac{3}{8}$ | | | | | |
| A | | 16 in $5\frac{1}{3}$ | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | 11 in $2\frac{3}{4}$ | 9 in $2\frac{1}{4}$ | 9 in $2\frac{1}{2}$ | 9 in $2\frac{7}{10}$ |
| F | | | | 12 in $3\frac{1}{3}$ | 12 in $3\frac{1}{3}$ | 12 in 4 | 12 in $4\frac{2}{10}$ |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | | | | |
| C | | | | | | | |
| BB | | | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| $GG^\#$ | | | | | | | |
| GG | | | | | | | |
| $FF^\#$ | | | | | | | |
| FF | 31 in 10 | 16 in $5\frac{1}{3}$ | | 12 in $3\frac{1}{3}$ | 12 in $3\frac{1}{3}$ | 12 in 4 | 12 in $4\frac{2}{10}$ |

## Table 8.6c
## Marking-out stick divisions for the 1796 DH

### Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll

| | 8FT BRIDGE PINS | 8FT TUNING PINS | 8FT TREBLE HITCHPINS | 8FT BASS HITCHPINS | 4FT TUNING PINS | 4FT BRIDGE PINS | 4FT HITCH PINS |
|---|---|---|---|---|---|---|---|
| $f^3$ | 6 in 1 | 12 in 5 | 8 in 7 | | | | |
| $e^3$ | | | | | | | |
| $e^{b3}$ | | | | | | | |
| $d^3$ | | | | | | | |
| $c^{\#3}$ | 6 in 1 | | | | | | |
| $c^3$ | 16 in 3 | | | | | | |
| $b^2$ | | | | | | | |
| $b^{b2}$ | | | | | | | |
| $a^2$ | | | | | | | |
| $g^{\#2}$ | | | | | | | |
| $g^2$ | | | | | | | |
| $f^{\#2}$ | | | | | | | |
| $f^2$ | | | | | | | |
| $e^2$ | | | | | | | |
| $e^{b2}$ | | | | | | | |
| $d^2$ | | | | | | | |
| $c^{\#2}$ | 16 in 3 | 12 in 5 | | | | | |
| $c^2$ | 14 in 3 | 9 in 4 | | | | | |
| $b^1$ | | | | | | | |
| $b^{b1}$ | | | | | | | |
| $a^1$ | | | | | | | |
| $g^{\#1}$ | | | | | | | |
| $g^1$ | | | | | | | |
| $f^{\#1}$ | 14 in 3 | | | | | | |
| $f^1$ | 4 in 1 | | | | | | |
| $e^1$ | | | | | | | |
| $e^{b1}$ | | | | | | | |
| $d^1$ | | | | | | | |
| $c^{\#1}$ | 4 in 1 | 9 in 4 | | | | | |
| $c^1$ | 31 in 10 | 8 in 5 | | | | | |
| b | | | | | | | |
| $b^b$ | | | | | | | |
| a | | | | | | | |
| $g^\#$ | | | | | | | |
| g | | | | | | | |
| $f^\#$ | | | | | | | |
| f | | | 8 in 7 | | | | |
| e | | | | 4 in 1 | | | |
| $e^b$ | | | | | | | |
| d | | | | | 4 in 1 | 18 in 5 | 10 in 3 |
| $c^\#$ | | | | | | | |
| c | | | | | | | |
| B | | | | | | | |
| $B^b$ | | 8 in 5 | | | | | |
| A | | 3 in 1 | | | | | |
| $G^\#$ | | | | | | | |
| G | | | | | | | |
| $F^\#$ | | | | 4 in 1 | 4 in 1 | 18 in 5 | 10 in 3 |
| F | | | | 18 in 5 | 18 in 5 | 3 in 1 | 20 in 7 |
| E | | | | | | | |
| $E^b$ | | | | | | | |
| D | | | | | | | |
| $C^\#$ | | | | | | | |
| C | | | | | | | |
| BB | | | | | | | |
| $BB^b$ | | | | | | | |
| AA | | | | | | | |
| $GG^\#$ | | | | | | | |
| GG | | | | | | | |
| $FF^\#$ | | | | | | | |
| FF | 31 in 10 | 3 in 1 | | 18 in 5 | 18 in 5 | 3 in 1 | 20 in 7 |

## THE BRUNSWICK MAKER BARTHOLD FRITZ IN RELATION TO THE HAMBURG SCHOOL

The uniformity and consistent high quality of Hamburg-made instruments must have had a decided effect upon other North-German makers, since the clavichords by craftsmen resident in cities from Brunswick in the south to Lübeck in the north have many of the characteristics (such as a set of 4ft strings in the bass) associated with Fleischer, Gerlach and Hass.[6] The close commercial ties enjoyed by Hamburg merchants with colleagues from other member cities of the Hanseatic League must have helped in the transmission of artistic styles, but composers and musicians, such as Nicolaus Strungk, also forged links with various centres.[7] The serving of an apprenticeship in Hamburg by the seventeenth-century Brunswick clavichord-maker Claus Dohausen (from 1631 to 1635) must also have helped in the dissemination of ideas from Hamburg to Brunswick.[8]

The clavichord built in Brunswick in 1751 by Barthold Fritz (and presently preserved at the Victoria and Albert Museum in London, inventory number 339-1882) is built very much in the Hamburg style. As with the clavichords made in Hamburg the instrument is designed for bi-chord stringing except in the bass where, from FF to c, there is an additional string of 4ft pitch. As with the Hamburg School the case sides, lid and baseboard are made from Scots pine. The baseboard too is constructed, like the baseboards of Fleischer, Hass and Gerlach clavichords, from two planks of pine butt-jointed together along their length. Furthermore,

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6 P. Williams, *The European Organ 1450-1850* (London: B.T. Batsford, 1966), p.97, has found a similar uniformity amongst the organs of North-West Germany and Scandinavia.

7 Nicolaus Strungk (1640-1700) was born in Brunswick, worked for the Elector Johann Friedrick of Hanover in 1665 and eventually became director of music in Hamburg in 1678.

8 D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.35.

although the actual case size of the Fritz clavichord, with the atypically wide compass of FF to $a^3$, is slightly larger than any surviving clavichord built by Hass, the length-to-width ratio is 13:4.

Perhaps most importantly, however, is that my work shows that Fritz used two calibrated sticks to mark out the position of the bridge pins, one for the 8ft bridge pins and one for the 4ft bridge pins. As shown in chapter 3, p.83, Fritz appears to have been using the Hanoverian Fuss, equivalent to 292.1mm. It is the Hanoverian Zoll (equivalent to 24.34mm) which has been used in the determination of Fritz's marking-out sticks given in tables 8.8a to 8.8c. A plot of the distance of each 4ft bridge pin and each near pin of a pair of 8ft bridge pins from the spine (see graph 8.4) revealed that the lateral spacing of the strings varies. The length of each segment on the graph is different when expressed in millimetres from that used by Hass, but when expressed in the local unit of measure the number of intervals between successive pairs of 8ft strings within one of the segments is the same (see table 8.8b). As with most five-octave clavichords of Hass one of the spacing groups of the 8ft strings is from $f^1$ to $f^2$, and like Hass the lateral width of this spacing group is 2½ Zolle. Fritz also uses one of the same regular divisions of whole numbers of Zolle as Hass. The spacing group F to $c^1$ of the 1751 BF, like the spacing group f to $f^1$ of most FF to $f^3$ clavichords of Hass, can be expressed as 18 divisions in 5 Zolle (see table 8.8c).

The Fritz clavichord does have a number of features which are not typical of the Hamburg School. Rosewood is used for the natural coverings, for example, and oak is used for the 8ft wrestplank, the balance rail and the 4ft wrestplank / bass 8ft hitchpin rail. The 4ft wrestplank sits on the baseboard and the 8ft bridge is backpinned from FF to $BB^b$. Also, the accidental blocks are more severely tapered towards their tails than the accidental blocks of Hamburg-made clavichords.

Contrary to the practice of either Fleischer, Hass or Gerlach, Fritz has signed his name in black on the soundboard in a line parallel to the diagonal row of tuning pins, and not parallel to the spine. Another Brunswick maker, Friedrich Carl Lemme (1747-1808), also signed his name in a line parallel to the tuning pins.

I have seen one Lemme clavichord. This is the clavichord built in Brunswick in 1766, and now at the Deutsches Museum, Munich, inventory number 20780. It appears to be built in the North-Germanic tradition as typified by members of the Hamburg School. I examined and measured the case dimensions of the instrument before I had developed my technique for measuring the bridge pins and so I am unable to confirm if this instrument was also marked out in the same way. From the precision and neatness of the workmanship, however, I suspect that it is exactly the same.

**THE EXPORT OF HASS INSTRUMENTS**

Throughout its history, Hamburg has had close ties with her Scandinavian neighbours to the north. During the ninth century missionaries from Hamburg introduced Christianity into Denmark, Norway and Sweden, and throughout the period of the Hanseatic League trade in Scandinavian iron, copper, timber and herring was particularly important to Hamburg. Ties with Denmark, due to its close proximity to Hamburg and because Denmark controlled the access to the Baltic, were also significant. During the seventeenth and eighteenth centuries, Hamburg musicians and composers appear to have had some influence on musical life in Copenhagen and Stockholm. Johann Schop, the leading municipal viol player in Hamburg from 1621 to his death in 1667, travelled to Copenhagen with Heinrich Schütz in 1634 to participate in the musical entertainment for the marriage of Prince Christian, son of King Christian IV (1577-1648).[9] The music collected by Gustaf Düben (circa 1628-1690) for use by the Swedish court orchestra in Stockholm included works by the

Hamburg composers Matthias Weckmann (circa 1619-1674) and Christoph Bernard (1628-1692).[10]

It was therefore natural that Hamburg instrument makers should have exported their instruments, and possibly their ideas, to Scandinavian countries.[11] The organ in the Trinitatis Kirke in Copenhagen was, for example, built by the Hamburg builder Hans Christoph Fritzsche between 1655 and 1660.[12] Hieronymus and Johann Hass continued this tradition and exported instruments to Norway, Denmark and Sweden. The 1723 HH harpsichord is thought to have been at Aalholm Castle, Denmark (the seat of the Raben-Levetzan family) from about 1730 until 1931 when it was bequeathed to the Musikhistoriska Museum in Copenhagen. It is likely that the 17(2)6 HH harpsichord at Leuvsta Bruk, Sweden, was bought as part of the rebuilding programme following the town's sacking by the Russians during the Great Northern War (1700-21). Since the organ in the local church (by Johann Niklas Cahman[13]) was installed at around the same time as the harpsichord in 1725, it is possible that the harpsichord may even have originally been intended for use in the church. The inventory made on the death of Johan Daniel Berlin (inventor, architect, instrument-maker and composer) in 1787 in Trondheim, Norway, gives a

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9 K. Stephenson, "Johann Schop," *The New Grove Dictionary of Music and Musicians*, ed. S. Sadie, vol.16 (London: MacMillan, 1980), p.732.

10 B. Kyhlberg, "Gustaf Düben," *The New Grove Dictionary of Music and Musicians*, ed. S. Sadie, vol.5. (London: MacMillan, 1980), pp.658-9.

11 According to L. A. Esteves Pereiva, "Two more Arp Schnitgers in Portugal?," *The Organ Yearbook*, XIV (1983), pp.17-22, the organ of Faro Cathedral (in Southern Portugal) was either built or at least installed by the Hamburg builder Johannes Hullenkampf in 1715 or 1716.

12 H. Klotz, "Gottfried Fritzsche," *The New Grove Dictionary of Music and Musicians*, ed. S. Sadie, vol.6 (London: MacMillan, 1980), p.858.

13 His father, Hans Heinrich Cahman I (died 1699), was the pupil and son-in-law of the Hamburg organ builder Hans Christoph Fritzsche.

number of Hamburg-made instruments.[14] The inventory includes the following instruments:

| | |
|---|---|
| 1. Et Clavicimbal af J. A. Hasse i Hamborg, 1749 tilligemed piano og forte Regiering af J. D. Berlin, med en Kasse, samt tvende Messing Lyseplader med Lysesax. | 1. A harpsichord by J. A. Hasse of Hamburg, 1749, fitted with soft and loud mechanism by J. D. Berlin, with a case and candle holders and candle scissors. |
| 5. En Viola da Gamba, med gule og brune Striber paa Siderne og Bagdelen, af Joachim Tielke, Hamborg 1706. | 5. A viola da gamba, with yellow and brown stripes on the sides and back, by Joachim Tielke, Hamburg, 1706. |
| 8.En Viola d'Amour af J. Tielke, Hamborg 1698. | 8. A viola d'amore by J. Tielke, Hamburg, 1698. |

Indeed, so great was the number of instruments being shipped to Sweden in the first half of the eighteenth century, that the government imposed a ban on the importation of musical instruments in 1756 to boost local manufacture.[15] Although Hamburg was not the only source of influence on Scandinavian makers[16] many early Swedish and Danish keyboard instruments closely resemble those of the Hamburg School.

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14 *Johan Daniel Berlin 1714-1787*, ed. K. Michelsen (Trondheim: Strindheim Trykkeris, 1987), p.22-3.

15 E. Nordenfelt-Åberg, "The harpsichord in 18th-century Sweden," *Early Music*, IX (1981), p.53.

16 According to D. Boalch, *Makers of the Harpsichord and Clavichord 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.169, Philip Specken studied instrument making in Dresden before moving to Stockholm.

## SIMILAR CHARACTERISTICS OF THE CLAVICHORDS OF HASS AND THE SCANDINAVIAN BUILDERS

Although organological research into Swedish clavichords is relatively new, it is clear from the studies of Eva Helenius-Öberg[17] that up until about 1740 Swedish clavichord-building drew heavily upon the Hamburg School. Most Swedish clavichord builders (such as G. Rackwitz, O. Broman, P. Lindholm and his son-in-law H. J. Söderström), for example, regularly provided their instruments with a set of octave strings in the bass. The earliest Swedish clavichord with a set of 4ft strings is that built by Johann Roos[18] in Stockholm in 1726, only four years later than the earliest surviving Hamburg-made clavichord with the tri-chord stringing in the bass that included a 4ft string.[19] Like most of the clavichords by Hass, Gerlach and Fleischer, the 4ft stringing of the 1726 Roos is taken up to the note d. Furthermore the 4ft bridge is slightly curved like the (1725) HH, the 1728 HH and the 1722 JF.

Despite the use of different local units of measure in Stockholm and in Hamburg in the eighteenth century, some Swedish clavichords have typical Hass dimensions. Not only was the Stockholm *Fot* considerably larger than the Hamburg Fuss,[20] it was also divided into ten *Tum*[21] rather than twelve Zolle. Neveretheless the case dimensions of the C to $d^3$ clavichord built by Roos in 1731 and another of the same compass built by Lars Kinström in 1752 are very similar to those of the (1725) HH.

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17 E. Helenius-Öberg, *Svenskt Klavikordbygge 1720-1820* (Stockholm: Almqvist & Wiksell International, 1986).

18 The instrument is located at the Jakobstad museum in Finland, inv.nr.384. Brief description and illustration in E. Helenius-Öberg, *Svenskt Klavikordbygge 1720-1820* (Stockholm: Almqvist & Wiksell International, 1986), pp.117-8.

19 It appears that in the 1720's and early 1730's the provision of a 4ft course was not yet standard. The clavichord built by Roos in 1731, and preserved at Malmö Museum, Sweden (inventory number 3.929) is, like the 1728 JF, simply bi-chord strung without a set of 4ft strings in the bass.

20 According to H. Heyde, *Musikinstrumentenbau 15-19 Jahrhundert Kunst-Handwerk Entwurf* (Leipzig: VEB Deutscher Verlag für Musik, 1986), p.78, 1 Stockholm Fot = 327.095mm, 1 Tum = 32.7mm and 1 Line = 3.27mm.

The case length and width of the two Swedish clavichords[22] together with those of the (1725) HH are given below in table 8.7 for comparison.

**Table 8.7.**
**Comparison of the case dimensions of the 1731 Roos, the 1752 Kinström and the (1725) HH**

| | (1725) H. Hass | | | 1731 J. Roos | | | 1752 L. Kinström | | |
|---|---|---|---|---|---|---|---|---|---|
| | Nominal | | Actual | Nominal | | Actual | Nominal | | Actual |
| | (Zolle) | (mm) | (mm) | (Tum) | (mm) | (mm) | (Tum) | (mm) | (mm) |
| Case Length | 63½ | 1516.0 | 1516 | 46¼ | 1512.4 | 1509 | 46¼ | 1512.4 | 1511 |
| Case Width | 17¾ | 423.8 | 423 | 13 | 425.1 | 423 | 12¾ | 416.9 | 414 |

Some of the early Swedish clavichords even have some of the decorative features associated with the clavichords of Fleischer, Hass and Gerlach. Many, for instance, have a stopped chamfer on the top right-hand edge of the 4ft wrestplank. Others, like the 1731 Roos have a typical Hass-type baseboard moulding cut directly into the baseboard along the length of the grain at the sides and across the grain at the ends. The accidental keylevers of some instruments, including that built in 1738 by Daniel Stråhle[23] and that constructed in 1759 by Gustaf Woltherssson[24] are carved in a wave-form pattern very similar to that used by Hieronymus Hass, Gerlach and Fleischer.

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21 Tum is one of the few words in Swedish in which the singular and plural form are the same. I am very grateful to Göran Grahn of Stockholm for pointing this out to me.

22 The measurements are from E. Helenius-Öberg, *Svenskt Klavikordbygge 1720-1820* (Stockholm: Almqvist & Wiksell International, 1986), pp.119 & 127.

23 The instrument is preserved at the Nordiska museet, Stockholm, inventory number 145.765.

24 The clavichord is at the Göteborgs Historiska Museum, inventory number 4772.

The clavichords of some Danish keyboard-instrument makers are also built in the North-Germanic tradition. An example is the clavichord built in Copenhagen in 1770 by Moritz Moshack.[25] The case sides, baseboard and lid of this instrument are made from pine, and the dimensions are very similar to the five-octave models of Hass built in the 1740's. As with the clavichords of the Hamburg School the 1770 Moshack has a stopped chamfer on the edge of the 4ft wrestplank. The brass strapwork hinges and keyflap lock are also in the same style as those used by Hass and Gerlach. Perhaps more significantly, however, is the fact that the corners of the case are secured, like the instruments built in the Hamburg workshops, with a dovetail joint with a mitre joint at the top for the case moulding. Rubbings of the four corners has revealed that the size and spacing of the five dovetails in each joint dovetails is exactly the same as that used by Hass. This of course begs a number of questions: were dovetail templates readily available from ironmongers; did Moshack buy in ready-built clavichord cases from Hamburg, mark them out, string them and then then sell them as his own work; or was he in fact apprenticed to Hass or Gerlach?

Analysis of the lateral spacing of the 4ft strings and the lateral pairwise spacing of the 8ft strings of the clavichord built in 1770 by Moshack has revealed an amazing similarity with the clavichords of Hass. As with the clavichords of Hass the 4ft strings are in two lateral spacing groups (FF to F and F to d) . Moreover, although Moshack was using the Copenhagen *Fod* and *Tom*,[26] the number of 4ft strings per local unit of measure in each spacing group is exactly the same as that used by Hass for the 4ft strings of the 1743b HH. The lateral spacing of the 8ft strings is also

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25 The instrument is located at the Musikhistorisk Museum og Carl Claudius' Samling, Copenhagen; inventory number A36.

26 According to H. Heyde, *Musikinstrumentenbau 15-19 Jahrhundert Kunst-Handwerk Entwurf* (Leipzig: VEB Deutscher Verlag für Musik, 1986), p.71, 1 Copenhagen Fod = 292.098mm, and 1 Tom = 24.34mm.

very similar to that used by Hass. As with the standard FF to $f^3$ clavichords of Hass there are four 8ft bridge pin groupings. However, whereas the four groupings of 8ft bridge pins with the same lateral spacing of standard FF to $f^3$ clavichords of Hass are: FF to f, f to $f^1$, $f^1$ to $f^2$ and $f^2$ to $f^3$; the four lateral spacing groups of the 1770 MM are: FF to f, f to $f^1$, $f^1$ to $c^3$ and $c^3$ to $f^3$. Nevertheless, the bottom two spacing groups (FF to f and f to $f^1$) have the same number of string pairs per unit of measure (24 in 7, and 12 in $3^1/_3$) as the 1732b HH, the 1742a HH, and the 1743b HH. The distances of the bridge pins from the spine of this clavichord are shown in table 8.8a, and plotted in graph 8.5. The spacing groups of the 8ft and 4ft strings are given in table 8.8b and the divisions on Moshack's marking-out stick are given in table 8.8c.

After about 1740, Swedish clavichord builders became increasingly under the influence of the Academy of Science in Stockholm, and consequently, many of the clavichords made during the second half of the eighteenth century and into the nineteenth century have a number of features which set them apart from the Hamburg School. Instruments have much larger compasses, the grain of the sound-board wood of clavichords built by Rackwitz, Lundborg and Kraft runs diagonally rather than parallel to the spine, the 8ft bridges are much straighter, and $c^2$ scalings of between 310 and 325mm indicate that iron was used as a stringing material in the treble rather than brass.

Nevertheless I have found that the bridges of two Swedish clavichords built at the end of the eighteenth century seem to have been marked out in the usual way. The two instruments in question are the unfretted clavichord made by Lindholm in Stockholm in 1798,[27] and the unfretted clavichord made by Rackwitz in Stockholm in 1796.[28]

Table 8.8a shows the distance of the 8ft and 4ft bridge pins from the spine when measured at right-angles to it. Plots of the bridge-pin measurements of the 1796 GR and the 1798 PL, with the origin moved from the spine to the position of the lowest note, are given as graphs 8.6 and 8.7 respectively. As has been shown for the clavichords of Hass, Gerlach, Fritz and Moshack, the plots reveal changes in the lateral string spacing by changes in the slope of the line joining the plotted points. Since both the 1796 GR and the 1798 PL have a compass of FF to $c^4$, and the 8ft bridges of these two instruments are much straighter than those of Hass, one would expect the spacing groups of the bridge pins to be significantly different. This is in fact the case. As shown in table 8.8b the 8ft strings of the 1796 GR have seven different spacing groups (FF to F, F to c, c to $c^1$, $c^1$ to $c^2$, $c^2$ to $f^2$, $f^2$ to $f^3$ and $f^3$ to $c^4$) and the 8ft strings of the 1798 PL have six different spacing groups (FF to F, F to c, c to $c^1$, $c^1$ to $c^2$, $c^2$ to $c^3$ and $c^3$ to $c^4$). The lateral width of each spacing group is also different from that used by Hass, because Rackwitz and Lindholm were using a different-sized inch. It is clear, however, that they were using the same principle of marking-out the position of the 8ft and 4ft bridge as other members of the North-Germanic tradition, since it is only when the pin positions are measured at right-angles to the spine of the instrument that the lateral spacing of the pins can be expressed as an integral number of pins in an integral number of Stockholm Tum (see table 8.8c).

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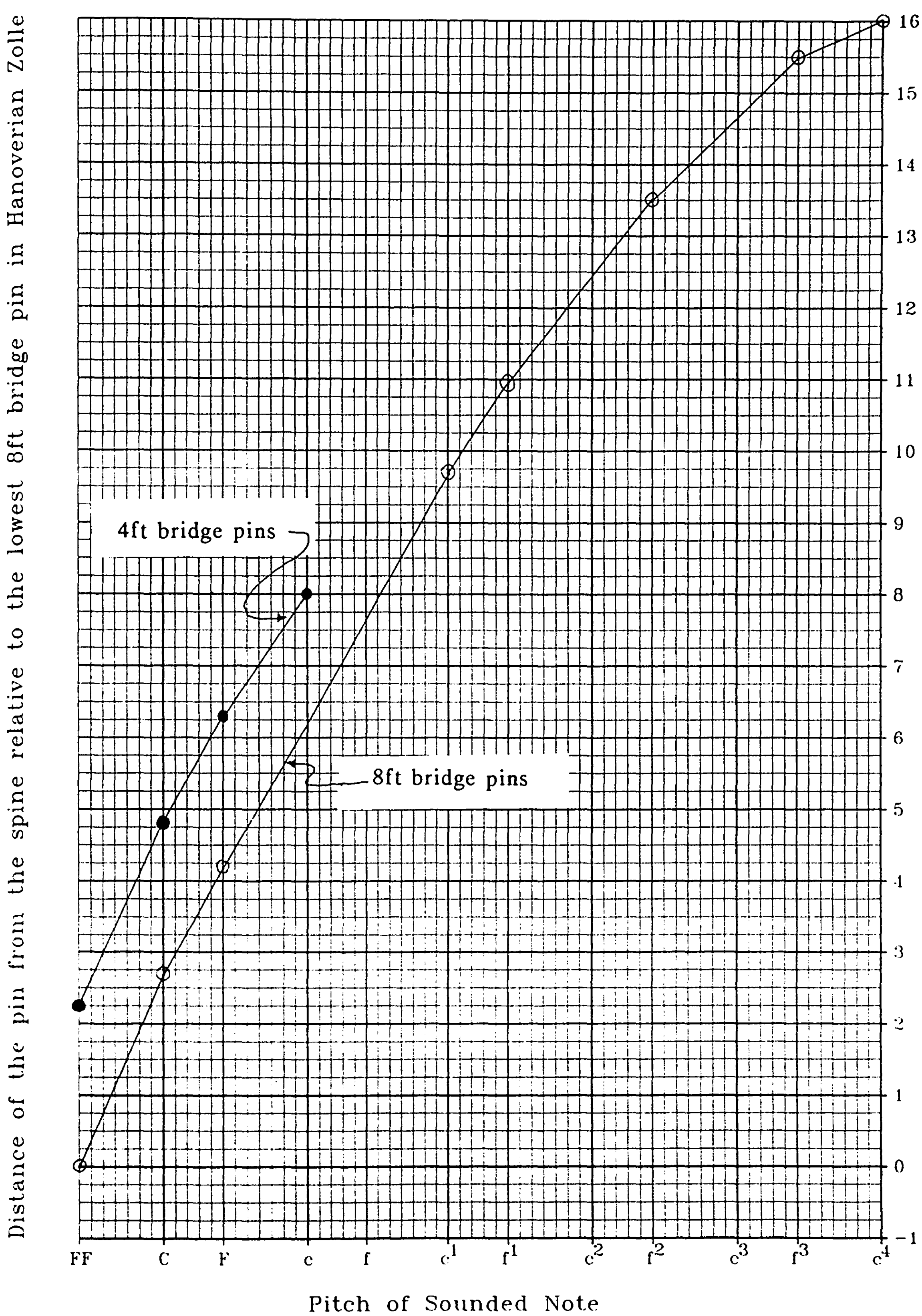
[27] The clavichord built by Lindholm in 1798 (Claudius Nº52) is preserved at the Musikhistorisk Museum og Carl Claudius' Samling, Copenhagen. It measures 62 Swedish Tum long (nominally 2027.4mm, actually 2026mm) by 18 Tum wide (nominally 588.6mm, actually 589mm) not including the thickness of the baseboard.

[28] The clavichord built in 1796 by Rackwitz is presently at the Russell Collection, University of Edinburgh, Cat. No.32. It measures $61^3/_4$ Tum long (nominally 2019.2mm, actually 2018mm) by 18 Tum wide (nominally 588.6mm, actually 592mm). For further measurements of this instrument see the catalogue entry, on pp.350-1.

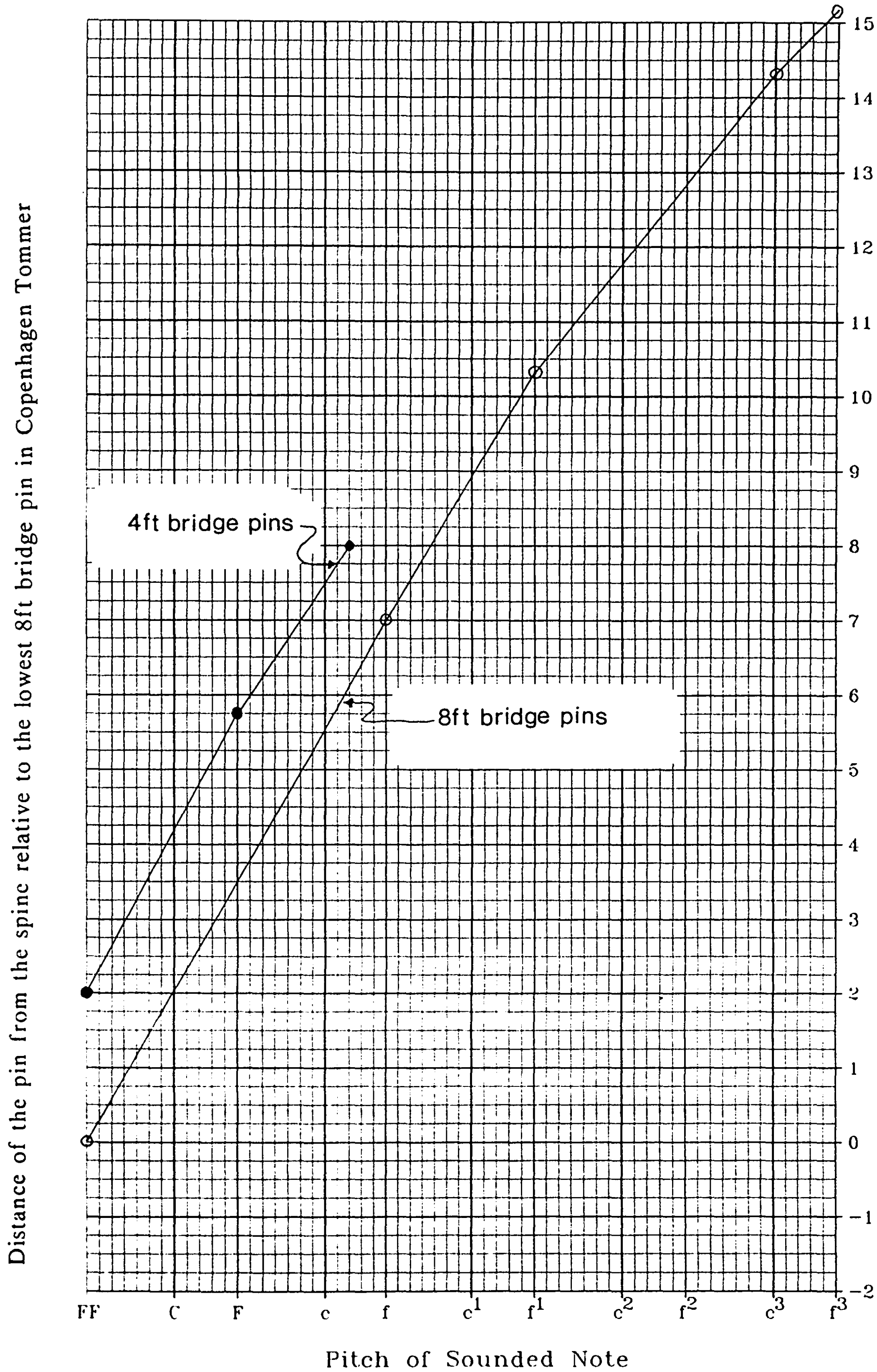
**Table 8.8a**
**Bridge-pin measurements from the spine**

| | 1751 FRITZ BRUNSWICK | | 1770 MOSHACK COPENHAGEN | | 1796 RACKWITZ STOCKHOLM | | 1798 LINDHOLM STOCKHOLM | |
|---|---|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $c^4$ | --- | | --- | | 36½ | | 35 | |
| $b^3$ | --- | | --- | | 40 | | 38½ | |
| $b^{b3}$ | --- | | --- | | 44 | | 41 | |
| $a^3$ | 42½ | | --- | | 47½ | | 43 | |
| $g^{\#3}$ | 46 | | --- | | 50 | | 47 | |
| $g^3$ | 49 | | --- | | 54 | | 50 | |
| $f^{\#3}$ | 52½ | | --- | | 58 | | 54 | |
| $f^3$ | 57 | | 35 | | 62 | | 58 | |
| $e^3$ | 61 | | 39 | | 66 | | 62 | |
| $e^{b3}$ | 65 | | 43 | | 69 | | 66 | |
| $d^3$ | 69 | | 46 | | 74 | | 70 | |
| $c^{\#3}$ | 73½ | | 50 | | 78 | | 74 | |
| $c^3$ | 78 | | 54 | | 82 | | 78 | |
| $b^2$ | 83 | | 58 | | 86 | | 83 | |
| $b^{b2}$ | 87 | | 63 | | 91 | | 88 | |
| $a^2$ | 91 | | 68½ | | 96 | | 93 | |
| $g^{\#2}$ | 95½ | | 73 | | 100 | | 98 | |
| $g^2$ | 100 | | 77½ | | 104 | | 102 | |
| $f^{\#2}$ | 104 | | 82½ | | 108 | | 107 | |
| $f^2$ | 108½ | | 87 | | 114½ | | 111 | |
| $e^2$ | 113 | | 92 | | 119 | | 116 | |
| $e^{b2}$ | 118 | | 96½ | | 124 | | 122 | |
| $d^2$ | 123 | | 101 | | 129 | | 126 | |
| $c^{\#2}$ | 128 | | 106 | | 134 | | 130½ | |
| $c^2$ | 133 | | 112 | | 138 | | 135½ | |
| $b^1$ | 137 | | 116 | | 142½ | | 140 | |
| $b^{b1}$ | 142 | | 122 | | 147 | | 144½ | |
| $a^1$ | 147½ | | 128 | | 152 | | 149 | |
| $g^{\#1}$ | 152 | | 133 | | 157 | | 154½ | |
| $g^1$ | 157 | | 139 | | 163 | | 160 | |
| $f^{\#1}$ | 162½ | | 144½ | | 168 | | 166 | |
| $f^1$ | 168 | | 150 | | 174½ | | 172½ | |
| $e^1$ | 173 | | 156½ | | 180 | | 178 | |
| $e^{b1}$ | 179 | | 162 | | 186½ | | 185 | |
| $d^1$ | 184 | | 169 | | 193 | | 192 | |
| $c^{\#1}$ | 190 | | 176 | | 199 | | 198 | |
| $c^1$ | 196½ | | 182 | | 206½ | | 206 | |
| b | 203 | | 189 | | 215 | | 214 | |
| $b^b$ | 210½ | | 196 | | 223 | | 224 | |
| a | 217 | | 202½ | | 232 | | 233½ | |
| $g^\#$ | 224 | | 209 | | 240 | | 242 | |
| g | 230 | | 215 | | 249 | | 251 | |
| $f^\#$ | 236 | | 222 | | 257 | | 261 | |
| f | 243 | | 229 | | 266 | | 270 | |
| e | 250 | | 236 | | 275 | | 279½ | |
| $e^b$ | 256 | | 242 | | 284 | | 289 | |
| d | 262 | | 249 | 196 | 292½ | | 298 | |
| $c^\#$ | 269 | | 256 | 203 | 301 | | 307 | |
| c | 276 | 225 | 264 | 208½ | 310 | 244 | 316 | 244½ |
| B | 282 | 230½ | 271 | 215 | 317 | 252 | 324½ | 252 |
| $B^b$ | 288½ | 237 | 278 | 221 | 324 | 259 | 332½ | 260 |
| A | 296 | 243½ | 284 | 226 | 332 | 266 | 341 | 267 |
| $G^\#$ | 302 | 249 | 292 | 232 | 340 | 273½ | 348 | 275 |
| G | 308 | 256 | 298 | 239½ | 348 | 281 | 358 | 283 |
| $F^\#$ | 316 | 262 | 306 | 246 | 355 | 290 | 365 | 290 |
| F | 323 | 269 | 313 | 253 | 362 | 297½ | 372 | 299 |
| E | 331 | 277 | 320 | 260 | 370 | 304 | 380 | 307 |
| $E^b$ | 338 | 283½ | 327 | 268 | 377 | 312 | 388 | 314½ |
| D | 346 | 291½ | 334 | 275 | 385 | 321 | 395 | 323 |
| $C^\#$ | 354 | 299 | 340 | 282½ | 391 | 330 | 401 | 333 |
| C | 361 | 307 | 346½ | 289 | 397 | 339 | 408 | 339 |
| BB | 370 | 316 | 354 | 297 | 404 | 345 | 414½ | 349 |
| $BB^b$ | 379 | 324½ | 361 | 304 | 411 | 354 | 421 | 358 |
| AA | 389 | 334 | 367 | 312 | 418½ | 363 | 427 | 367 |
| $GG^\#$ | 398 | 343 | 374½ | 320 | 425 | 372 | 436 | 377 |
| GG | 407 | 352½ | 381½ | 327 | 432 | 381½ | 443 | 386 |
| $FF^\#$ | 416 | 361 | 388 | 334½ | 440½ | 391 | 451½ | 396 |
| FF | 425 | 370 | 395½ | 343 | 448 | 401 | 460 | 407 |

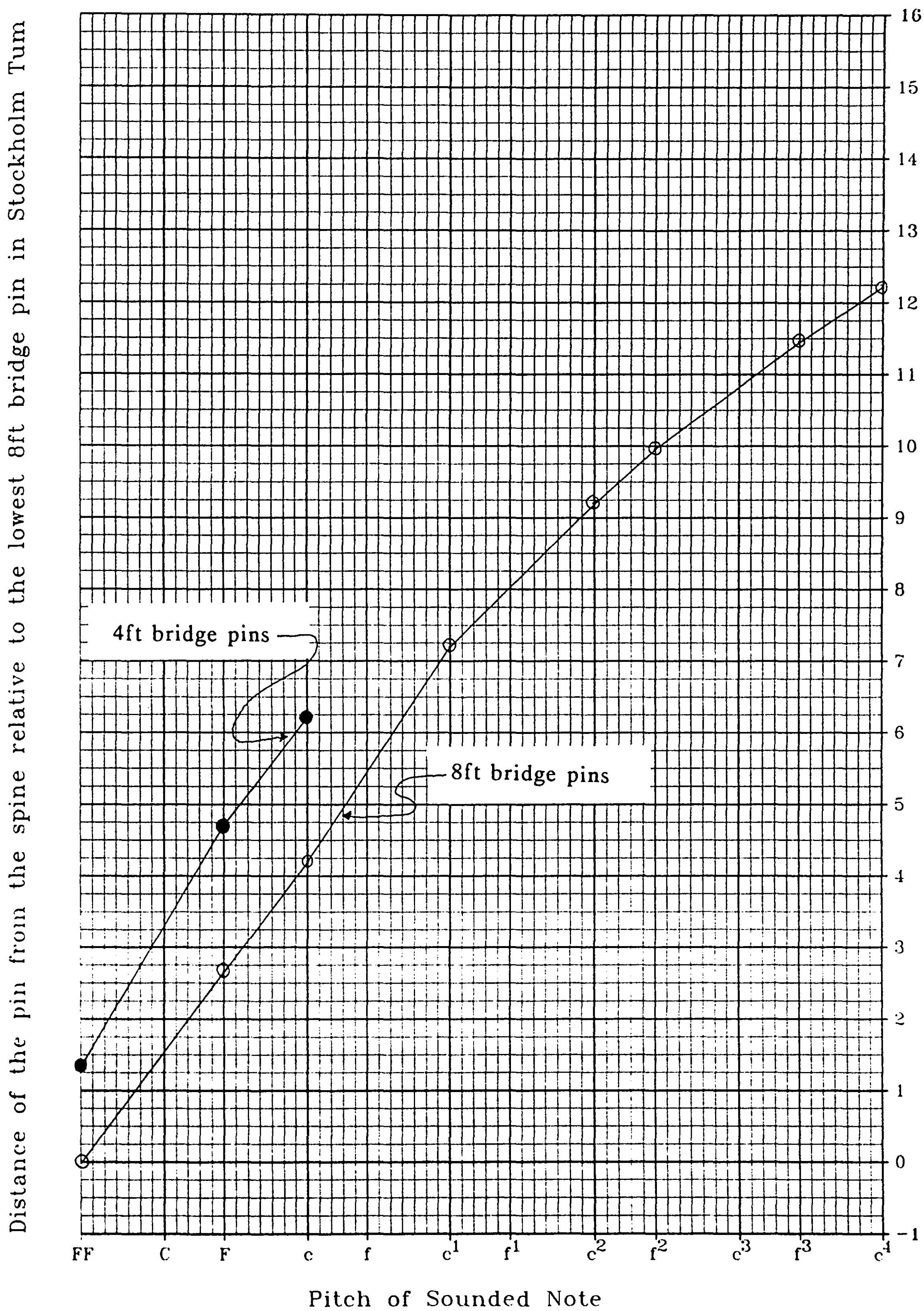
**Graph 8.4**
**Bridge pin positions of the 1751 BF**



**Graph 8.5**
**Bridge pin positions of the 1770 MM**



**Graph 8.6**
**Bridge pin positions of the 1796 GR**



**Graph 8.7**
**Bridge pin positions of the 1798 PL**

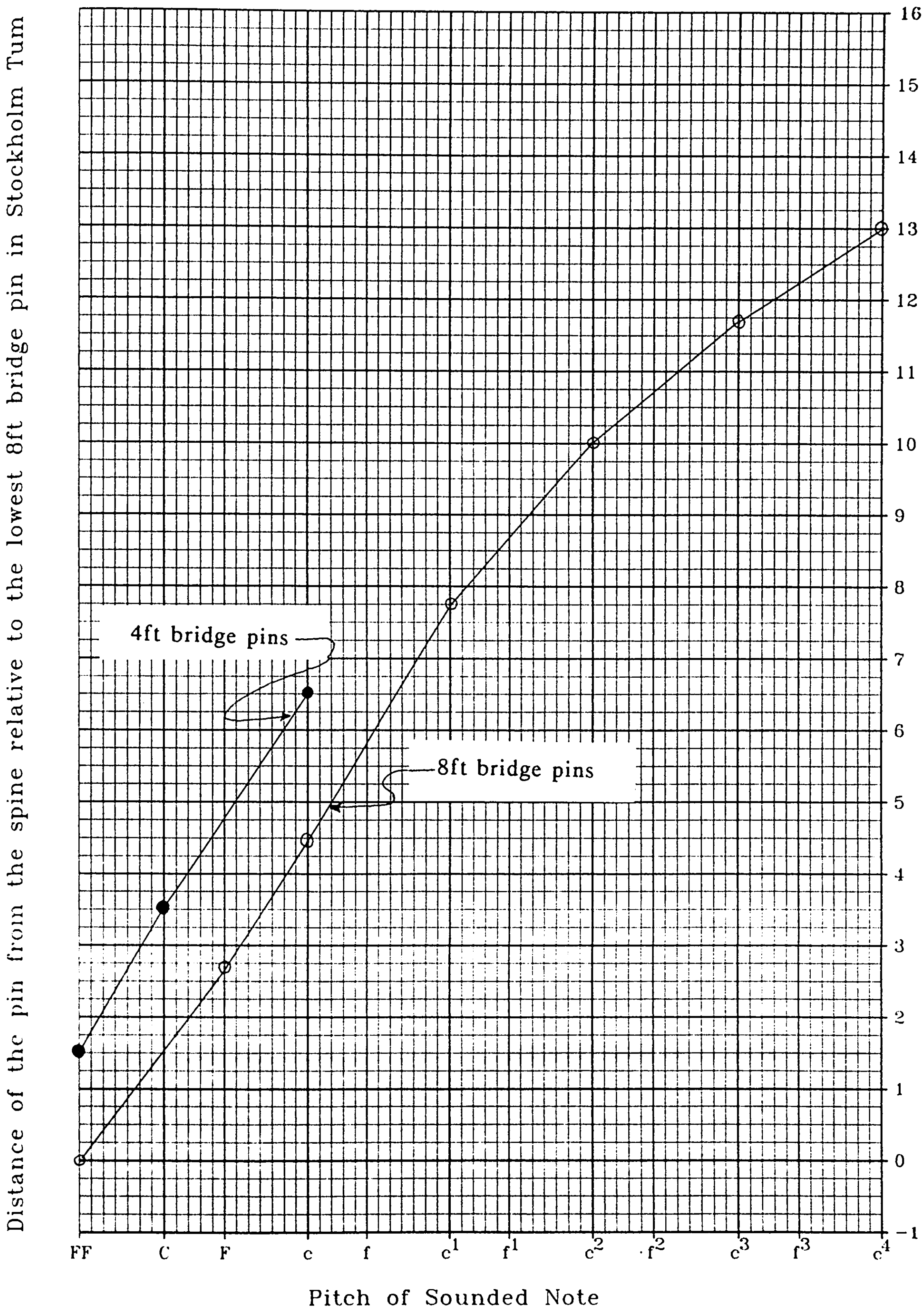


**Table 8.8b.**
**Number of string pairs per local unit of measure**

| | 1751 FRITZ BRUNSWICK (Zolle) | | 1770 MOSHACK COPENHAGEN (Tommer) | | 1796 RACKWITZ STOCKHOLM (Tum) | | 1798 LINDHOLM STOCKHOLM (Tum) | |
|---|---|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $c^4$ | | | | | 7 in 3/4 | | 12 in 1 1/3 | |
| $b^3$ | | | | | | | | |
| $b^{b3}$ | | | | | | | | |
| $a^3$ | 4 in ½ | | | | | | | |
| $g^{\#3}$ | | | | | | | | |
| $g^3$ | | | | | | | | |
| $f^{\#3}$ | 4 in ½ | | | | 7 in 3/4 | | | |
| $f^3$ | 12 in 2 | | 5 in 5/6 | | 12 in 1½ | | | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | 5 in 5/6 | | | | 12 in 1 1/3 | |
| $c^3$ | | | 19 in 4 | | | | 12 in 1 2/3 | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | 12 in 2 | | | | 12 in 1½ | | | |
| $f^2$ | 12 in 2½ | | | | 5 in 3/4 | | | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | 5 in 3/4 | | 12 in 1 2/3 | |
| $c^2$ | | | | | 12 in 2 | | 12 in 2¼ | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | 12 in 2½ | | 19 in 4 | | | | | |
| $f^1$ | 5 in 1¼ | | 12 in 3 1/3 | | | | | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | 5 in 1¼ | | | | 12 in 2 | | 12 in 2¼ | |
| $c^1$ | 19 in 5 5/18 | | | | 12 in 3 | | 12 in 3 1/3 | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| g# | | | | | | | | |
| g | | | | | | | | |
| f# | | | 12 in 3 1/3 | | | | | |
| f | | | 24 in 7 | | | | | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| d | | | | 9 in 2¼ | | | | |
| c# | | | | | 12 in 3 | | 12 in 3 1/3 | |
| c | | 7 in 1 3/4 | | | 7 in 1½ | 7 in 1½ | 7 in 1 3/4 | 12 in 3 |
| B | | | | | | | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| G# | | | | | | | | |
| G | | | | | | | | |
| F# | 19 in 5 5/18 | 7 in 1 3/4 | | 9 in 2¼ | 7 in 1½ | 7 in 1½ | 7 in 1 3/4 | |
| F | 5 in 1½ | 5 in 1½ | | 12 in 3 3/4 | 12 in 2 2/3 | 12 in 3 1/3 | 12 in 2 2/3 | |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| C# | 5 in 1½ | 5 in 1½ | | | | | | 12 in 3 |
| C | 7 in 2 2/3 | 7 in 2 2/3 | | | | | | 7 in 2 |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| GG# | | | | | | | | |
| GG | | | | | | | | |
| FF# | | | | | | | | |
| FF | 7 in 2 2/3 | 7 in 2 2/3 | 24 in 7 | 12 in 3 3/4 | 12 in 2 2/3 | 12 in 3 1/3 | 12 in 2 2/3 | 7 in 2 |

**Table 8.8c.**
**Marking-out stick divisions in local units of measure**

| | 1751 FRITZ BRUNSWICK (Zolle) 8ft | 1751 FRITZ BRUNSWICK (Zolle) 4ft | 1770 MOSHACK COPENHAGEN (Tommer) 8ft | 1770 MOSHACK COPENHAGEN (Tommer) 4ft | 1796 RACKWITZ STOCKHOLM (Tum) 8ft | 1796 RACKWITZ STOCKHOLM (Tum) 4ft | 1798 LINDHOLM STOCKHOLM (Tum) 8ft | 1798 LINDHOLM STOCKHOLM (Tum) 4ft |
|---|---|---|---|---|---|---|---|---|
| $c^4$ | | | | | 28 in 3 | | 9 in 1 | |
| $b^3$ | | | | | | | | |
| $b^{b3}$ | | | | | | | | |
| $a^3$ | 8 in 1 | | | | | | | |
| $g^{\#3}$ | | | | | | | | |
| $g^3$ | | | | | | | | |
| $f^{\#3}$ | 8 in 1 | | | | 28 in 3 | | | |
| $f^3$ | 6 in 1 | | 6 in 1 | | 8 in 1 | | | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | 6 in 1 | | | | 9 in 1 | |
| $c^3$ | | | 19 in 4 | | | | 36 in 5 | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | 6 in 1 | | | | 8 in 1 | | | |
| $f^2$ | 24 in 5 | | | | 20 in 3 | | | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | 20 in 3 | | 36 in 5 | |
| $c^2$ | | | | | 6 in 1 | | 16 in 3 | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | 24 in 5 | | 19 in 4 | | | | | |
| $f^1$ | 4 in 1 | | 18 in 5 | | | | | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | 4 in 1 | | | | 6 in 1 | | 16 in 3 | |
| $c^1$ | 18 in 5 | | | | 4 in 1 | | 18 in 5 | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| $g^\#$ | | | | | | | | |
| g | | | | | | | | |
| $f^\#$ | | | 18 in 5 | | | | | |
| f | | | 24 in 7 | | | | | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| d | | | | 4 in 1 | | | | |
| $c^\#$ | | | | | 4 in 1 | | 18 in 5 | |
| c | | 4 in 1 | | | 14 in 3 | 14 in 3 | 4 in 1 | 4 in 1 |
| B | | | | | | | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| $G^\#$ | | | | | | | | |
| G | | | | | | | | |
| $F^\#$ | 18 in 5 | 4 in 1 | | 4 in 1 | 14 in 3 | 14 in 3 | 4 in 1 | |
| F | 10 in 3 | 10 in 3 | | 16 in 5 | 9 in 2 | 18 in 5 | 9 in 2 | |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| $C^\#$ | 10 in 3 | 10 in 3 | | | | | | 4 in 1 |
| C | 21 in 8 | 21 in 8 | | | | | | 7 in 2 |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| $GG^\#$ | | | | | | | | |
| GG | | | | | | | | |
| $FF^\#$ | | | | | | | | |
| FF | 21 in 8 | 21 in 8 | 24 in 7 | 16 in 5 | 9 in 2 | 18 in 5 | 9 in 2 | 7 in 2 |

## CONCLUSION

It has become clear during the course of this research that the clavichords built in the workshops of Hieronymus and Johann Hass are of a very sophisticated and beautiful design. The degree of accuracy found in their marking-out of the joints, the soundboard and the bridges is very impressive, and clearly the result of considerable care and attention to detail. There is, however, much research still necessary if we are to gain a clear understanding of just some of the principles involved in the basics of general clavichord design. And it is, I believe, perhaps in the area of eighteenth-century Swedish and Danish clavichord building - countries where large numbers of un-restored instruments survive - that seems the most likely source of deepening our knowledge and understanding of the North-Germanic tradition of clavichord building.

## CATALOGUE OF HASS CLAVICHORDS

### (1725) HH

**Hieronymus Albrecht Hass, circa 1725 fretted clavichord**

Köpings Museum, Köping, Sweden, inventory number 00.538

Signature: no longer legible

Case dimensions:

Length 1516, with baseboard 1521, inside length 1484
Width 423, with mouldings 434, inside width 393
Right-hand case front 682
Soundboard to top of case 31.3
Height of case sides 94, with baseboard 119
Keywell length 704

Keyboard:

Compass C to $d^3$, 51 notes
4ft strings from C to d
Naturals of ivory
Sharps of black-stained beech topped with a plate of ebony
Arcades of embossed leather. The pattern is very worn, but may include a lily.

String scalings (approximate):

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | *126* | *273.9* | | | |
| $c^3$ | 146 | 284.0 | | | |
| $f^2$ | *220* | *296.3* | | | |
| $c^2$ | 288 | 291.0 | | | |
| $f^1$ | *427* | *288.3* | | | |
| $c^1$ | 580 | 289.5 | | | |
| f | *837* | *279.0* | d | - bridge broken - | |
| c | *1026* | *253.8* | c | *632* | *303.5* |
| F | *1209* | *198.6* | F | *813* | *265.1* |
| C | *1315* | *161.5* | C | *947* | *231.5* |

Fretting:

Unfretted from C to d and then fretted in pairs from $e^b$ upwards apart from the notes a, $d^1$, $a^1$ and $d^2$ which are free; the pairs of notes $a^2$-$b^{b2}$, $b^2$-$c^3$ and $c^{\#3}$-$d^3$ are also fretted together.

Gauge Numbers:

The gauge numbers are illegible from C to $b^b$; the rest are: b 4, $c^1$ to $b^1$ 5, $c^2$ to $a^2$ 6, $b^{b2}$ to $d^3$ 7.

Description:

This instrument may be the earliest surviving clavichord by Hieronymus Hass. Unfortunately, the instrument is in a very poor condition: the main lid, keyflap, nameboard and seven keylevers (for the notes C, a, b, $d^1$, $e^1$, $e^2$ and $b^2$) are missing; the 4ft wrestplank and tool box backing piece have become detached from the rest of the instrument; the soundboard painting and signature have suffered serious water damage; and the top end of the 4ft bridge is missing. Since many of the keylevers are badly warped, and the guide tongues are either broken or lost the string scalings could only be measured approximately - these are consequently given in italics.

I have allocated a date of circa 1725 to the instrument for the following reasons: 1) the 4ft bridge is slightly curved like other dated instruments from the 1720's (the 1728 HH, the 1722 JF and the 1723 JF), 2) the fretting pattern is more 'primitive' than any other Hass instrument, and 3) unlike any other Hass clavichord there is no moulding on either end of the baseboard.

Literature:

Illustrated and decribed in E. Helenius-Öberg, *Svenskt Klavikordbygge 1720-1820* (Stockholm: Almqvist & Wiksell International, 1986), pp.156-8.

Former owner:

Mr E. Ericsson, Västra Sörby, Munktorp, Sweden. He presented the instrument to the museum at the beginning of the twentieth century.

**1728 HH**

**Hieronymus Albrecht Hass, 1728 fretted clavichord**

Berlin Musikinstrumentenmuseum, Berlin, inventory number 0344

Signature: "H. A. Hass Fecit / Hambg 1728"

Case dimensions:

Length 1514, with baseboard mouldings 1532, inside length 1484

Width 432, with baseboard mouldings 442½, inside width 402

Right-hand case (present) 636, (original) ≈ 685

Soundboard to top of case 32.0

Height of case sides 120, with baseboard 146½

Keywell length (present) 757, (original) ≈ 705

Keyboard:

Original compass C to $d^3$, 51 notes, presently C to $f^3$, 54 notes

4ft strings from C to d

Three-octave span 491

Total width of keys at keyfronts, C to $d^3$ (original) 705, 30 naturals

Naturals of tortoise-shell

Sharps of unstained lime topped with a chevron plate of ivory and tortoise-shell

Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 122 | 273.9 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 222 | 296.3 | | | |
| $c^2$ | 291 | 291.0 | | | |
| $f^1$ | 432 | 288.3 | | | |
| $c^1$ | 579 | 289.5 | | | |
| f | 836 | 279.0 | d | 576 | 323.3 |
| c | 1015 | 253.8 | c | 607 | 303.5 |
| F | 1190 | 198.6 | F | 794½ | 265.1 |
| C | 1292 | 161.5 | C | 926 | 231.5 |

Fretting:

Unfretted from C to d, then fretted in pairs from $e^b$ upwards, apart from all the d's and a's which are free.

Description:

This, the earliest signed and dated clavichord by Hieronymus Hass, has been altered from its original state. The original C to $d^3$ compass was increased in the treble by three notes, by re-positioning the treble keywell brace and extending the rack, balance rail, keywell flap and namebatten. To accommodate the three extra keys the left-hand side of the soundboard was trimmed, leaving the curved 4ft bridge very close to the edge. There was only enough space for two extra pairs of bridge pins, hitch pins and tuning pins, so the notes $e^{b3}$ and $e^3$ are fretted together.

The reddish-brown outer case paintwork obscures the original decoration, and the instrument is on four later turned legs. The decoration of the lid interior (consisting of a complicated geometrical design and a small central painting of a lyre-player riding on a dolphin) is, however, authentic.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.3a. Illustrated in J. Montagu, *The World of Baroque and Classical Musical Instruments* (Newton Abbot: David and Charles, 1979), p.76. Technical drawing by Horst Rase (Berlin, July 1991).

**1732b HH**

**Hieronymus Albrecht Hass, 1732 unfretted Clavichord**

Hamburg Museum für Kunst und Gewerbe, inventory number 1903.754

Signature: "Hieronymus Albrecht Hass fecit. / Hamburg Anno 1732"

Case dimensions:

Length 1709, with baseboard mouldings 1731, inside length 1679
Width 496, with baseboard mouldings 501, inside width 468
Right-hand case front (present) 776, (original) 730
Soundboard to top of case 36.3
Height of case sides 139, with baseboard 170
Keywell length present 835-845, original 798

Keyboard:

Original compass FF to $d^3$, 58 notes, extended to FF to $f^3$
4ft strings from FF to d
Length of top original key 441½, bottom key 412
Three-octave span 490
Naturals of ivory (not original)
Sharps of ebonised lime topped with a plate of ebony
Arcades of incised white paper or parchment on red background

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 126½ | 284.0 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 212 | 283.0 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 422½ | 282.0 | | | |
| $c^1$ | 574 | 287.0 | | | |
| f | 832 | 277.6 | d | 568 | 318.8 |
| c | 999 | 249.8 | c | 618 | 309.0 |
| F | 1206 | 201.2 | F | 786 | 262.2 |
| C | 1324 | 165.5 | C | 916 | 229.0 |
| FF | 1465 | 122.2 | FF | 1103 | 184.0 |

Gauge Numbers:

FF to GG 00, GG$^{\#}$ to C 0, C$^{\#}$ to F 1, F$^{\#}$ to B$^{b}$ 2, B to e 3, f to b 4, c$^{1}$ to b$^{1}$ 5, c$^{2}$ to a$^{2}$ 6, b$^{b2}$ to d$^{3}$ 7

Description:

This is a much altered example of the only extant FF to d$^{3}$ Hass clavichord. The compass was extended by three notes in much the same way as the 1728 HH. Although Pilipczuk has suggested that the alteration was undertaken by Hass himself this seems unlikely, since the quality of the workmanship of the alteration is poor in comparison with the rest of the instrument. Also the e$^{b3}$ key does not have the waveform carving of the other accidental keylevers, and the 8ft bridge has been extended by a small piece of brass! The 8ft bridge is presently backpinned from FF to B$^{b}$, but plugged holes indicate that the back-pinning was originally to e. As with so many clavichords the original outer-case decoration is obscured by a later overpainting. The stand is not original.

Former owner:

The instrument was bought by the Musuem in 1903 from the Widow Schweitzer aus Neuengamme in den Vierlanden, Hamburg.

Literature:

Documented and illustrated in A. Pilipczuk, "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (1988), pp.42-52. More detailed analysis in K. Hummitzsch, F. Lebas & A. Pilipczuk, "Das Hieronymus-Albrecht-Hass-Clavichord von 1732 und seine Restaurierung," *Arbeitsblätter für Restauratoren* (Römisch-Germanisches Zentralmuseum Mainz, 1991), pp.129-34. Technical drawing by Ingo Kötter.

**1740a HH**

**Hieronymus Albrecht Hass, 1740 fretted Clavichord**

Stiftelsen Musikkulturens Framjande (Nydahl Coll.), Stockholm,
inventory number KL 47

Signature: "Hieronym. Alb. Hass in Hamb 1740"

Case dimensions:

Length 1517, with baseboard mouldings 1539½, inside length 1489
Width 432, with baseboard mouldings 435, inside width 405
Right-hand case front 685
Soundboard to top of case 37.7
Height of case sides 118, with baseboard 148
Keywell length 702

Keyboard:

Compass C to $d^3$, 51 notes
4ft strings from C to d
Length of top key 381½, bottom key 359½
Three-octave span 489½
Total width of keys at keyfronts 699.5, 30 naturals
Naturals of tortoise-shell
Sharps of solid horn with inset plate of engraved mother-of-pearl
Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 126 | 282.9 | | | |
| $c^3$ | 143 | 286.0 | | | |
| $f^2$ | 215 | 287.0 | | | |
| $c^2$ | 286 | 286.0 | | | |
| $f^1$ | 430 | 287.0 | | | |
| $c^1$ | 570 | 285.0 | | | |
| f | 815 | 272.0 | d | 569 | 319.3 |
| c | 1003 | 250.8 | c | 619 | 309.5 |
| F | 1195 | 199.4 | F | 805 | 268.6 |
| C | 1302 | 162.8 | C | 943 | 235.8 |

Fretting:

Unfretted from C to d, then fretted in pairs from $e^b$ upwards, apart from all the d's and the a's which are free.

Description:

The instrument appears to have been one of the most elaborately decorated of all Hass instruments. The interior of the lid is lacquered red, and decorated with chinoiserie in gold and black. The 4ft wrestplank and rack are veneered in olive wood, and there is an ivory and tortoise-shell bead moulding let into the top edge. The nameboard is veneered in olive wood, tortoise-shell, ivory and engraved mother-of-pearl. The soundboard is painted with flowers and a female lutenist. Unfortunately, the original outer-case and lid decoration is hidden beneath a thick coat of light-blue paint.

This is one of the few remaining Hass clavichords which survives with its original stand. The stand basically consists of an upper frame (in which there are two drawers), which is supported by four cabriole legs. Each of the legs terminates in a cloven hoof.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.6a.

**1740b HH**

**Hieronymus Albrecht Hass, 1740 fretted Clavichord**

Private ownership, Lyngby, near Copenhagen, Denmark

Signature: "Hieronym. Alb. Hass / in Hambg 1740"

Case dimensions:

Length 1514, with baseboard mouldings 1534, inside length 1487
Width 428½, with baseboard mouldings 434½, inside width 401
Right-hand case front 689½
Soundboard to top of case 31.9
Height of case sides 109½, with baseboard 140
Keywell length 705

Keyboard:

Compass C to $d^3$, 51 notes
4ft strings from C to d
Length of top key 380, bottom key 356
Three-octave span 492
Total width of keys at keyfronts 703, 30 naturals
Distance top to bottom rack slots 719
Naturals of ivory
Sharps of ebonised lime topped with a plate of ebony
Arcades mostly missing, originally incised white paper on a red ground

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 121 | 271.6 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 220 | 293.7 | | | |
| $c^2$ | 287½ | 287.5 | | | |
| $f^1$ | 434 | 289.7 | | | |
| $c^1$ | 574 | 287.0 | | | |
| f | 823 | 274.6 | d | 577 | 323.8 |
| c | 1012½ | 253.1 | c | 630 | 315.0 |
| F | 1197 | 199.7 | F | 802½ | 267.8 |
| C | 1301 | 162.6 | C | 936 | 234.0 |

Fretting:

Unfretted from C to d, then fretted in pairs from $e^b$ upwards, apart from all the d's and the a's which are free.

Gauge Numbers:

C to D 0, $E^b$ to F 1, $F^\#$ to A 2, $B^b$ to d 3, $e^b$ to a 4, $b^b$ to $b^1$ 5, $c^2$ to $d^3$ 6

Description:

The external decoration, stand and keywell flap date from the time of the restoration in 1969. A silver plaque on the 4ft wrestplank is inscribed: "Restaureret 1969 / af Instrumentmager / Hans Holm / Slagelse." Unusually, the keys are numbered in black ink on the underside, from the bass upwards. This appears to be original since it is in the same hand as the signature on the soundboard. A detail from the lid painting is given below:

**Plate C.1**
**A detail from the painting on the lid interior of the 1740b HH**

Former history:

The instrument was discovered by the author in 1991. It appears to have been used at Sorø Akademi (a school about 75 km from Copenhagen) since the eighteenth century. Interestingly, during the eighteenth century the sons of German nobility who settled in Denmark were educated at the school. The instrument was rescued from the school rubbish dump by the present owner's mother in 1969.

Literature:

There are no references to this instrument in the literature.

**1742a HH**

**Hieronymus Albrecht Hass, 1742 unfretted Clavichord**

Museum für Hamburgische Geschichte

Signature: "Hieronym. Albr. Hass / In Hambg Anno 1742"

Case dimensions:

Length 1698, with baseboard mouldings 1719½,inside length 1665

Width 524, with baseboard mouldings 537, inside width 490

Right-hand case front 728

Soundboard to top of case 35.2

Height of case sides 138, with baseboard 167

Keywell length 843

Keyboard:

Compass FF to $f^3$, 61 notes

4ft strings from FF to d

Length of top key 464, bottom key 422

Three-octave span 490

Total width of keys at keyfronts 839

Naturals of ivory

Sharps of black-stained lime topped with a plate of tortoise-shell

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 105 | 280.3 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 213 | 284.3 | | | |
| $c^2$ | 284 | 284.0 | | | |
| $f^1$ | 426 | 284.3 | | | |
| $c^1$ | 570 | 285.0 | | | |
| f | 813 | 271.3 | d | 572 | 321.0 |
| c | 986 | 246.5 | c | 616½ | 308.3 |
| F | 1189 | 198.4 | F | 777 | 259.3 |
| C | 1304 | 163.0 | C | 900 | 225.0 |
| FF | 1445 | 120.6 | FF | 1080 | 180.2 |

Description:

Together with the 1742b HH this is the earliest extant five-octave Hass clavicord. It is also one of the few Hass clavichords to retain its original back touchrail cloth, consisting of two layers of red woven cloth stitched together. The soundboard is painted with flowers. Since the brown-coloured paint on the outer-case covers two large screws (driven into the 4ft wrestplank from the outside of the left-hand case end) it cannot be original.

For an illustration of the toolbox lid see figure 7.5, p.228.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.7. Recorded and illustrated in A. Pilipczuk "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (1988), pp.42 & 46. Illustrated in G. Jaacks, *Musikleben in Hamburg zur Barockzeit* (Hamburg: Museum für Hamburgische Geschichte, 1978), p.4.

Former owner:

The clavichord was presented to the museum by a D. J. Barthels in 1899.

**1742b HH**

**Hieronymus Albrecht Hass, 1742 unfretted Clavichord**

Schloss Bergedorf, Hamburg

Signature: "Hieronym. Albr. Hass / In Hambg Anno 1742"

Case dimensions:

- Length 1703, with mouldings 1726,inside length 1673
- Width 520, with baseboard 520, inside width 490
- Right-hand case front 733
- Soundboard to top of case 37.5
- Height of case sides 140½, with baseboard 170½
- Keywell length 845

Keyboard:

- Compass FF to $f^3$, 61 notes
- 4ft strings from FF to d
- Length of top key 466, bottom key 425
- Three-octave span 492
- Total width of keys at keyfronts 842
- Naturals of ivory
- Sharps of black-stained lime topped with a plate of ebony
- Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 106 | 283.0 | | | |
| $c^3$ | 143 | 286.0 | | | |
| $f^2$ | 215 | 287.0 | | | |
| $c^2$ | 286 | 286.0 | | | |
| $f^1$ | 424 | 283.0 | | | |
| $c^1$ | 569 | 284.5 | | | |
| f | 824 | 275.0 | d | 572 | 321.0 |
| c | 1004 | 251.0 | c | 618 | 309.0 |
| F | 1205 | 201.0 | F | 782½ | 261.1 |
| C | 1316 | 164.5 | C | 908½ | 227.1 |
| FF | 1453 | 121.2 | FF | 1090 | 181.9 |

Gauge Numbers:

FF to GG 000, GG# to BB$^b$ 00, BB to D 0, E$^b$ to F 1, F# to A 2, B$^b$ to f 3, f# to b 4, $c^1$ to $b^1$ 5, $c^2$ to $d^3$ 6, $e^{b3}$ to $f^3$ 7

Description:

The decoration on the outer case and on the interior of the lid appears to be an overpainting. The red paint on the soundboard moulding, and on the inside of the case above the soundboard is also not original. For an illustration of the original toolbox lid see figure 7.6, p.229.

This is clearly the same model of clavichord as the 1742a HH, since the rack-slot spacing pattern and the shape of the 8ft bridge are common to both instruments. The instrument is, however, the only known Hass clavichord with a lock fitted into the rear side of the toolbox backing piece.

Literature:

Recorded and illustrated in A. Pilipczuk "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (1988), pp.46-7.

Former owner:

The clavichord was obtained from a private owner in 1893.

**Plate C.2 The 1742b HH**

**1743a HH**

**Hieronymus Albrecht Hass, 1743 unfretted Clavichord**

Bate collection, University of Oxford. Recently purchased from the Taphouse Collection.

Signature: "Hieronym. Albr. Hass / in Hamb 1743"

Case dimensions:

- Length 1702, with baseboard mouldings 1725,inside length 1673
- Width 521, with baseboard mouldings 539, inside width 489
- Right-hand case front 729
- Soundboard to top of case 36.5
- Height of case sides 132, with baseboard 164
- Keywell length 842

Keyboard:

- Compass FF to $f^3$, 61 notes
- 4ft strings from FF to d
- Three-octave span 490
- Total width of keys at keyfronts 840½
- Naturals of ivory
- Sharps of black-stained lime topped with a chevron plate of ivory and ebony
- Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 104 | 277.6 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 216 | 288.3 | | | |
| $c^2$ | 287 | 287.0 | | | |
| $f^1$ | 434 | 289.7 | | | |
| $c^1$ | 577 | 288.5 | | | |
| f | 828 | 276.3 | d | 583 | 327.2 |
| c | 1016 | 254.0 | c | 630 | 315.0 |
| F | 1216 | 203.0 | F | 798 | 266.3 |
| C | 1326 | 165.8 | C | 926 | 231.5 |
| FF | 1460 | 121.8 | FF | 1111 | 185.4 |

Gauge Numbers:

FF to GG 000, GG$^{\#}$ to BB$^{b}$ 00, BB to D 0, E$^{b}$ to F 1, F$^{\#}$ to A 2, B$^{b}$ to e 3, f to b 4, c$^{1}$ to b$^{1}$ 5, c$^{2}$ to d$^{3}$ 6, e$^{b3}$ to f$^{3}$ 7

Fretting:

Unfretted, apart from e$^{b3}$-e$^{3}$

Description:

The fretting of this instrument is a very odd, and possibly the result of an error in the marking-out of the position of the 8ft bridge pins. This theory is discussed further in chapter 3, p.59, of the present work.

The painting on the inside of the lid of the 1743a HH shows either Orpheus or Apollo surrounded by some of the muses. The soundboard is left unpainted.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.8. See also *Checklist of the Bate Collection of Historical Instruments*, (March, 1988).

Former history:

The instrument was probably that shown by J. B. Cramer & Co. at the International Inventions Exhibition in 1885.

**1743b HH**

**Hieronymus Albrecht Hass, 1743 unfretted Clavichord**

Musikhistoriska Museet, Copenhagen, Claudius Collection no 49

Signature: "Hieronym. Albr. Hass / in Hambg Anno 1743"

Case dimensions:

Length 1700, with baseboard mouldings 1727, inside length 1667½
Width 518, with baseboard mouldings 546, inside width 491
Right-hand case front 728
Soundboard to top of case 34.8
Height of case sides 139, with baseboard 168
Keywell length 841½

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to d
Length of top key 466, bottom key 422
Three-octave span 489
Total width of keys at keyfronts 839
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 105 | 280.3 | | | |
| $c^3$ | 139 | 278.0 | | | |
| $f^2$ | 210 | 280.3 | | | |
| $c^2$ | 282 | 282.0 | | | |
| $f^1$ | 421 | 281.0 | | | |
| $c^1$ | 564 | 282.0 | | | |
| f | 807 | 269.3 | d | 574 | 322.1 |
| c | 985 | 246.3 | c | 617 | 308.5 |
| F | 1197 | 199.7 | F | 778 | 259.6 |
| C | 1318 | 164.8 | C | 904 | 226.0 |
| FF | 1458 | 121.6 | FF | 1083 | 180.7 |

Gauge Numbers:

FF to GG 000, GG# to BB$^b$ 00, BB to D 0, E$^b$ to F 1, F# to A 2, B$^b$ to e$^b$ 3, e to b 4, c$^1$ to b$^1$ 5, c$^2$ to d$^3$ 6, e$^{b3}$ to f$^3$ 7

Description:

The present outer case decoration, consisting of red stripes on a cream-coloured ground, is not original. The inside of the lid has a painting of six of the muses, including a flautist, lute player and viol player. This is exactly the same as the lid painting on the 1744b HH in the Stiftelsen Musikkulturens Framjande, Stockholm. For an illustration of the toolbox lid see figure 7.4, p.227.

The baseboard is atypical of most Hass clavichords in that it has an applied moulding. It is glued along the sides and ends of the baseboard and is mitred at each of the four corners. Since the baseboard moulding has the usual Hass profile it is probably original. It is interesting to note that Hass also applied a normal clavichord baseboard moulding to the baseboard of the 1734 HH harpsichord.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.9.

Former owner:

Acquired by Carl Claudius sometime before 1930.

**1744a HH**

**Hieronymus Albrecht Hass, 1744 unfretted Clavichord**

Brussels Conservatoire, inventory number 2518

Signature: "Hieronymus Albr. Hass / Hamb 1744"

Case dimensions:

Length 1714½, with baseboard mouldings 1737, inside length 1685
Width 519, with baseboard mouldings 538, inside width 490
Right-hand case front 742½
Soundboard to top of case 34.5
Height of case sides 138, with baseboard 167
Keywell length 845

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to d
Length of top key 465, bottom key 420
Three-octave span 492
Total width of keys at keyfronts 842
Naturals of ivory
Sharps of black-stained lime topped with a plate of tortoise-shell
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 104 | 277.6 | | | |
| $c^3$ | 140 | 280.0 | | | |
| $f^2$ | 215½ | 287.7 | | | |
| $c^2$ | 287½ | 287.5 | | | |
| $f^1$ | 433½ | 289.3 | | | |
| $c^1$ | 572 | 286.0 | | | |
| f | 820 | 273.6 | d | 591 | 331.7 |
| c | 1010 | 252.5 | c | 638 | 319.0 |
| F | 1213 | 202.4 | F | 805 | 268.6 |
| C | 1322 | 165.3 | C | 931 | 232.8 |
| FF | 1458 | 121.6 | FF | 1116 | 186.2 |

Description:

The outer case and stand are painted black, with gilt mouldings. The name-board and inside keywell faces are veneered in olive wood. The interior of the lid is decorated with 18th-century engravings of musicians, wild animals and a view of Altona (which is today a suburb of Hamburg). The view is entitled 'Prospekt Der Daenischen Handels-stadt Altona, von Süden Gesehen 1746', and is signed Philipp Oeding (1697-1781).

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.10. Recorded and illustrated in S. Paganelli, *Musical Instruments from the Renaissance to the 19th Century* (London: Hamlyn, 1970), pp.66 and 68.

Former owner:

The clavichord was an exchange with the Musikhistoriska Museet, Copenhagen.

**1744b HH**

**Hieronymus Albrecht Hass, 1744 unfretted Clavichord**

Stiftelsen Musikkulturens Framjande, Stockholm, inventory number KL 48

Signature: "Hieronym. Albr. Hass / Hamburg Anno 1744"

Case dimensions:

- Length 1719, with baseboard mouldings 1739, inside length 1686
- Width 520, with baseboard mouldings 534, inside width 491
- Right-hand case front 745
- Soundboard to top of case 33.9
- Height of case sides 139½, with baseboard 169½
- Keywell length 843

Keyboard:

- Compass FF to $f^3$, 61 notes
- 4ft strings from FF to d
- Length of top key 467, bottom key 418
- Three-octave span 490
- Total width of keys at keyfronts 840
- Naturals of ivory
- Sharps of black-stained lime topped with a plate of tortoise-shell
- Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 104 | 277.6 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 215 | 287.0 | | | |
| $c^2$ | 287 | 287.0 | | | |
| $f^1$ | 430 | 287.0 | | | |
| $c^1$ | 570 | 285.0 | | | |
| f | 822 | 274.3 | d | 582 | 326.6 |
| c | 1009 | 252.3 | c | 628 | 314.0 |
| F | 1212 | 202.2 | F | 798 | 266.3 |
| C | 1325 | 165.6 | C | 925 | 231.3 |
| FF | 1462 | 122.0 | FF | 1115 | 186.0 |

Gauge Numbers:

FF to GG 000, GG# to $BB^b$ 00, BB to D 0, $E^b$ to F 1, F# to A 2, $B^b$ to e 3, f to b 4, $c^1$ to $b^1$ 5, $c^2$ to $d^3$ 6, $e^{b3}$ to $f^3$ 7

Description:

The outer-case covering of brown paint probably hides the original case decoration. The inside of the lid is, however, probably decorated with its original painting, since it is of the same design as that found on the lid interior of the 1743b HH in Copenhagen.

Inside the toolbox is a spool of iron wire. The reel on which the wire is wound is marked in black ink with the number 6. The un-oxidised wire has a diameter of 0.35 mm, but this is unfortunately not consistent with the Hamburg Gauge System.

The rack has been radically altered, probably towards the end of the eighteenth century or at the beginning of the nineteenth century, perhaps in Sweden. The keys are now guided between two small slips of wood added to either side of each original rack slot. This non-original keylever guide system prevented me from making a rubbing of the position of the rack slots, and therefore being able to make a comparison with the other clavichords of Hieronymus Hass.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.10a.

**1746 JH**

**Johann Adolph Hass, 1746 fretted Clavichord**

Koldinghus Museum, inventory number 292

Signature: "J. A. Hass / Hambg 1746"

Case dimensions:

Length 1574, with baseboard mouldings 1594, inside length 1548

Width 445, with baseboard mouldings 458, inside width 419

Right-hand case front 743

Height of case sides 116, with baseboard 146½

Keywell length 707

Keyboard:

Compass C to $d^3$, 51 notes

4ft strings from C to d

Length of top key 395, bottom key 373

Three-octave span 492

Total width of keys at keyfronts 704

Naturals of ivory

Sharps of black-stained lime topped with a chevron plate of ebony and ivory

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 123½ | 277.2 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 219 | 292.3 | | | |
| $c^2$ | 290 | 290.0 | | | |
| $f^1$ | 435 | 290.3 | | | |
| $c^1$ | 563½ | 281.8 | | | |
| f | 828 | 276.3 | d | 560 | 314.3 |
| c | 1020 | 255.0 | c | 611 | 305.5 |
| F | 1219 | 203.4 | F | 799 | 266.6 |
| C | 1336 | 167.0 | C | 942 | 235.5 |

Fretting:

Unfretted from C to e, then fretted in pairs from f upwards, apart from all the d's and the a's which are free.

Gauge Numbers:

C to D 0, $E^b$ to F 1, $F^\#$ to A 2, $B^b$ to $e^b$ 3, e to b 4, $c^1$ to $a^1$ 5, $b^{b1}$ to $d^3$ 6

Description:

This is the earliest surviving clavichord by Johann Hass. The original outer-case paintwork is hidden beneath a crude wood-graining decoration, and the instrument is on four later turned legs. The decoration on the lid interior is, however, original and consists of several moths, a crown and the monogram 'EMJ' in gold and black on a red-lacquered ground. This monogram may have been the initials of the original owner.

There is a crudely-made (and therefore not original) circular hole in the soundboard, approximately 49 mm diameter, at the bass end of the 4ft bridge.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.10b.

Former owner:

The instrument was bought by the museum in 1892 from Mrs Freiesleben of Brørup, for the sum of 30Kr.

**1747 JH**

**Johann Albrecht Hass, 1747 unfretted Clavichord**

Norsk Folkemuseum, Oslo, inventory number 950-97

Signature: "J. A. Hass / Hambg 1747"

Case dimensions:

Length 1725, with baseboard mouldings 1743½, inside length 1695

Width 532, with baseboard mouldings 542, inside width 502

Right-hand case front 751

Soundboard to top of case 36.6

Height of case sides 138, with baseboard 168

Keywell length 843

Keyboard:

Compass FF to $f^3$, 61 notes

4ft strings from FF to d

Length of top key 477½, bottom key 432

Three-octave span 490

Total width of keys at keyfronts 840

Naturals of ivory

Sharps of black-stained lime topped with a plate of ebony

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 104 | 277.6 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 216 | 288.3 | | | |
| $c^2$ | 288 | 288.0 | | | |
| $f^1$ | 438 | 292.3 | | | |
| $c^1$ | 570 | 285.0 | | | |
| f | 827 | 276.0 | d | 600 | 336.7 |
| c | 1010 | 252.5 | c | 648 | 324.0 |
| F | 1215 | 202.7 | F | 815 | 272.0 |
| C | 1336 | 167.0 | C | 941 | 235.3 |
| FF | 1481 | 123.6 | FF | 1125 | 187.7 |

Gauge Numbers:

FF to GG 000, GG$^{\#}$ to BB$^{b}$ 00, BB to D 0, E$^{b}$ to F 1, F$^{\#}$ to A 2, B$^{b}$ to e 3, f to b 4, c$^{1}$ to b$^{1}$ 5, c$^{2}$ to d$^{3}$ 6, e$^{b3}$ to f$^{3}$ 7

Description:

The stand appears to be original, and like the stand under the 1740a HH each of the four cabriole legs terminates in a cloven hoof.

There are the remains of brown felt-like balance cloths positioned along the top of the balance rail. Unfortunately the cloths have disintegrated to such an extent that it is impossible to measure their thickness without damaging them. It is not known, however, if the balance cloths are an original feature of this instrument, or a Scandinavian modification since only two other Hass clavichords are provided with balance cloths.

The lid painting, consisting of various musicians, appears to have been left in a state of incompleteness.

**Plate 8.3 The lid painting of the 1747 JH**

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.11. Illustrated in F. J. Hirt, *Meisterwerke des Klavierbaus* (Olten: URS Graf, 1955), p.317.

Former history:

The instrument came to the Museum in 1897.

**1748 JH**

**Johann Albrecht Hass, 1748 unfretted Clavichord**

Grassi Museum, University of Leipzig.

Signature: "J. A. Hass / Hambg 1748"

Case dimensions:

- Length 1672, with baseboard mouldings 1686, inside length 1642
- Width 512, with baseboard mouldings 522, inside width 486
- Right-hand case front 772
- Soundboard to top of case 32.5
- Height of case sides 135, with baseboard 157
- Keywell length 768

Keyboard:

- Compass GG to $d^3$, 56 notes
- 4ft strings from GG to d
- Length of top key 457½, bottom key 415
- Three-octave span 485
- Total width of keys at keyfronts 767
- Naturals of ivory
- Sharps of black-stained lime topped with a plate of tortoise-shell
- Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 124 | 278.4 | | | |
| $c^3$ | 143 | 286.0 | | | |
| $f^2$ | 215½ | 287.7 | | | |
| $c^2$ | 286½ | 286.5 | | | |
| $f^1$ | 431 | 287.7 | | | |
| $c^1$ | 561 | 280.5 | | | |
| f | 808 | 269.6 | d | 575 | 322.7 |
| c | 991 | 247.8 | c | 623 | 311.5 |
| F | 1195 | 199.4 | F | 796 | 265.6 |
| C | 1315 | 164.4 | C | 927 | 231.8 |
| GG | 1420 | 133.0 | GG | 1060 | 198.5 |

Description:

This is one of only two surviving instruments by Hass with a compass of GG to $d^3$. The other is the 1734 HH harpsichord. This clavichord may have been made as a special request since Hass marked out the bridges and the 4ft wrestplank with standard five-octave FF to $f^3$ sticks.

The instrument is in a relatively poor state of repair. For example the lid is missing, and the soundboard has suffered serious water damage. Most of the flowers on the soundboard are dis-figured, and the gauge numbers are virtually illegible.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.11a. Described and illustrated in H. Henkel, *Clavichorde, Musikinstrumenten-Museum der Karl-Marx Universität, Katalog, Band 4* (Leipzig: VEB Deutscher Verlag für Musik, 1981), Cat. No.26, pp.59-61.

**1755 JH**

**Johann Adolph Hass, 1755 unfretted Clavichord**

Musikhistorisk Museum, Copenhagen, inventory number A 19

Signature: "J. A. Hass / Hambg 1755"

Case dimensions:

- Length 1720, with baseboard mouldings 1732, inside length 1689
- Width 527, with baseboard mouldings 535, inside width 497
- Right-hand case front 755
- Soundboard to top of case 33.9
- Height of case sides 139, with baseboard 171
- Keywell length 848

Keyboard:

- Compass FF to $f^3$, 61 notes
- 4ft strings from FF to d
- Length of top key 472, bottom key 419
- Three-octave span 492
- Total width of keys at keyfronts 845
- Naturals of ivory
- Sharps of black-stained lime topped with a plate of tortoise-shell and ivory
- Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 105 | 280.3 | | | |
| $c^3$ | 144 | 288.0 | | | |
| $f^2$ | 212 | 283.0 | | | |
| $c^2$ | 283 | 283.0 | | | |
| $f^1$ | 420 | 280.3 | | | |
| $c^1$ | 566 | 283.0 | | | |
| f | 811 | 270.6 | d | 584 | 327.8 |
| c | 988 | 247.0 | c | 627 | 313.5 |
| F | 1195 | 199.4 | F | 795 | 265.3 |
| C | 1315 | 164.4 | C | 923 | 230.8 |
| FF | 1470 | 122.6 | FF | 1117 | 186.4 |

Description:

The instrument was restored in 1901 by Hornung and Muller. Consequently the tuning pins and the balance pins are modern replacements, and some of the flowers on the soundboard have been retouched. A folding music desk has been attached to the rear face of the nameboard. The outer-case decoration and the stand also date from the early part of the twentieth century.

The inside of the lid is decorated with coloured chinoiserie on a yellow (originally white?) background, in the same style as that on the lid of the 1732a HH harpsichord. For an illustration of the toolbox lid see figure 7.7, p.230.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.12. Illustrated in A. Conradt, "Hamburger Musikinstrumente des 18. Jahrhunderts mit lackmalerei," *Jahrbuch der Hamburger Kunstsammlungen*, IX (1964), p.43. Illustrated in F. Hirt, *Meisterwerke des Klavierbaus* (Olten: URS Graf, 1955), p.318.

**1756 JH**

**Johann Adolph Hass, 1756 fretted Clavichord**

Smithsonian Institution, Washington, USA, inventory number 1980.0020.01

Signature: "J. A. Hass / Hambg Anno 1756"

Case dimensions:

Length 1565, with baseboard mouldings 1577, inside length 1534
Width 448.5, with baseboard mouldings 466, inside width 419
Right-hand case front 740
Soundboard to top of case 32.0
Height of case sides 117, with baseboard 144
Keywell length 707

Keyboard:

Compass C to $d^3$, 51 notes
4ft strings from C to d
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 123 | 276.1 | | | |
| $c^3$ | 140 | 280.0 | | | |
| $f^2$ | 217½ | 290.3 | | | |
| $c^2$ | 287½ | 287.5 | | | |
| $f^1$ | 427 | 285.0 | | | |
| $c^1$ | 563 | 281.5 | | | |
| f | 817 | 272.6 | d | 586 | 328.9 |
| c | 1005 | 251.3 | c | 637 | 318.5 |
| F | 1214 | 202.6 | F | 822 | 274.3 |
| C | 1331 | 166.4 | C | 968 | 242.0 |

Fretting:

Unfretted from C to e, then fretted in pairs from f upwards, apart from all the d's and all the a's which are free.

Gauge Numbers:

C to D 0, $E^b$ to F 1, $F^\#$ to A 2, $B^b$ to $e^b$ 3, e to b 4, $e^1$ to $b^1$ 5, $c^2$ to $d^3$ 6.

Description:

I have not been able to measure this instrument in person, so all the measurements given for this instrument are taken from the technical drawing. Using the technical drawing I have been able to verify that the rack-slot spacing pattern and the shape of the 8ft bridge are exactly the same as the 1761b JH.

At present the outer case is plain wood, but it is likely that the instrument was originally painted.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.12a. Technical drawing by Thomas Wolf, 1981.

Former owner:

Property of the Peabody Conservatory, Baltimore until 1980.

**1760b JH**

**Johann Adolph Hass, 1760 unfretted Clavichord**

Museum für Kunst und Gewerbe, Hamburg

Signature: "J. A. Hass / Hambg Anno 1760"

Case dimensions:

Length 1719½, with baseboard mouldings 1736, inside length 1684
Width 527½, with baseboard mouldings 542, inside width 495
Right-hand case front 751
Soundboard to top of case 34.5
Height of case sides 140, with baseboard 166
Keywell length 847

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to d
Length of top key 468½, bottom key 417
Three-octave span 492
Total width of keys at keyfronts
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 107 | 285.7 | | | |
| $c^3$ | 142½ | 285.0 | | | |
| $f^2$ | 214 | 285.7 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 427 | 285.0 | | | |
| $c^1$ | 572 | 286.0 | | | |
| f | 811 | 270.6 | d | 600 | 336.7 |
| c | 990 | 247.5 | c | 645 | 322.5 |
| F | 1193 | 199.1 | F | 812½ | 271.1 |
| C | 1310 | 163.8 | C | 939 | 234.8 |
| FF | 1457 | 121.6 | FF | 1123½ | 187.5 |

Description:

The instrument is very important, because it retains a number of old, probably original features. There are the remains of action cloths along the top of the balance rail, and on the back touchrail. Some of the bass 8ft and 4ft strings may also be eighteenth century.

The outer case, lid and stand are all painted black. The inside of the lid is painted vermilion, with a small central painting of a female standing beside a Greek-style urn. The soundboard is left unpainted.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.13. Recorded and illustrated in A. Pilipczuk "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (1988), pp.46 and 48.

Former owner:

Acquired by the Museum in 1904 from the legacy of the Hamburg piano-maker Adolf Kohl (1847-1902).

**1761a JH**

**Johann Adolph Hass, 1761 unfretted Clavichord**

Musikhistorisk Museum, Copenhagen, inventory number A 40

Signature: "J. A. Hass / Hambg Anno 1761"

Case dimensions:

Length 1729½, with baseboard mouldings 1748, inside length 1694
Width 522, with mouldings 530, inside width 489
Right-hand case front 754
Soundboard to top of case 34.5
Height of case sides 137½, with baseboard 168
Keywell length 846

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to B
Length of top key 462, bottom key 408
Three-octave span 492
Total width of keys at keyfronts 843½
Naturals of ivory, with ebony arcades
Sharps of black-stained lime topped with a plate of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 105 | 280.3 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 216 | 288.3 | | | |
| $c^2$ | 284 | 284.0 | | | |
| $f^1$ | 425 | 283.7 | | | |
| $c^1$ | 564 | 282.0 | | | |
| f | 807 | 269.3 | | | |
| c | 1001 | 250.3 | B | 664 | 313.4 |
| F | 1210 | 201.9 | F | 813 | 271.3 |
| C | 1328 | 166.0 | C | 944 | 236.0 |
| FF | 1471½ | 122.8 | FF | 1138 | 189.9 |

Fretting:

Unfretted from FF to e, then fretted in pairs from f upwards, apart from all the d's and a's which are free. The top note, $f^3$, is also free.

Gauge Numbers:

FF to GG 000, GG# to $BB^b$ 00, BB to D 0, $E^b$ to F 1, F# to A 2, $B^b$ to $e^b$ 3, e to b 4, $c^1$ to $f^{\#2}$ 5, $g^2$ to $d^3$ 6, $e^{b3}$ to $f^3$ 7.

Description:

This is the only Hass clavichord which is triple-strung throughout the compass. The instrument is designed for two 8ft choirs plus a 4ft choir from FF to B, and then three 8ft choirs from c to $f^3$. One extra string has been added to the treble end of the 8ft bridge, such that the top four notes ($d^3$ to $f^3$) are presently unfretted, and both $e^3$ and $f^3$ are simply bi-chord strung. Hass may have been trying to design a potentially louder clavichord, for in addition to the triple stringing the gauge numbers on the soundboard indicate slightly heavier stringing than normal.

Former owners:

Possibly belonged to the Danish composer C F Weyse (1774-1842). The clavichord was later owned by the Danish singer Albert Meyer (1839-1921) whose heirs gave it to the Museum in 1926.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.13a.

**1761b JH**

**Johann Adolph Hass, 1761 fretted Clavichord**

Musikhistorisk Museum, Copenhagen, Claudius collection number A 50

Signature: "J. A. Hass / Hambg Anno 1761"

Case dimensions:

Length 1567, with baseboard mouldings 1585, inside length 1538
Width 448, with baseboard mouldings 460, inside width 422
Right-hand case front 736
Soundboard to top of case 31.5
Height of case sides 116, with baseboard 145
Keywell length 709

Keyboard:

Compass C to $d^3$, 51 notes
4ft strings from C to d
Length of top key 395½, bottom key 364
Three-octave span 493
Total width of keys at keyfronts 706½
Naturals of ivory
Sharps of black-stained lime topped with a chevron plate of ebony and ivory
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 122 | 273.9 | | | |
| $c^3$ | 143½ | 287.0 | | | |
| $f^2$ | 218 | 291.0 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 437½ | 292.0 | | | |
| $c^1$ | 567 | 283.5 | | | |
| f | 829 | 276.6 | d | 582 | 326.6 |
| c | 1017 | 254.3 | c | 631½ | 315.8 |
| F | 1221 | 203.7 | F | 820 | 273.6 |
| C | 1328 | 166.0 | C | 957 | 239.3 |

Fretting:

Unfretted from C to e, then fretted in pairs from f upwards, apart from all the d's and the a's which are free.

Gauge Numbers:

C to D 0, $E^b$ to F 1, $F^\#$ to A 2, $B^b$ to $e^b$ 3, e to b 4, $c^1$ to $b^1$ 5, $c^2$ to $d^3$ 6

Description:

The inside of the lid is decorated with coloured engravings of hunting scenes and eight separate engravings of members of the Habsburg-Lorraine dynasty. These include the Empress Maria Theresa and her husband Francis I, and the Emperor Joseph II. There are also portraits of Frederick V of Denmark and Norway, and Aldophus Fridericus of Sweden. The exterior of the case is painted in brown with imitation wood graining. The stand is not original. An inscription on the baseboard reads : 'Reperarad av / N. Nilsson Instrumentfabrik, / Malmö i Nov. 1899 / af / P. [Msr?] D. Brock'. According to Grant O'Brien some of the 8ft and 4ft brass stringing may be old and possibly eighteenth century.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.14.

**1761c JH**

**Johann Adolph Hass, 1761 unfretted Clavichord**

Private ownership, Cambridge

Signature: "J. A. Hass / Hambr Anno 1761"

Case dimensions:

Length 1729, baseboard not original, inside length 1697
Width 534, baseboard not original, inside width 500
Right-hand case front 763
Height of case sides 138, with baseboard 168
Keywell length 848

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to c
Length of top key 477, bottom key 422
Three-octave span 491
Total width of keys at keyfronts 845½
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 102 | 272.3 | | | |
| $c^3$ | 140 | 280.0 | | | |
| $f^2$ | 212 | 283.0 | | | |
| $c^2$ | 287 | 287.0 | | | |
| $f^1$ | 424 | 283.0 | | | |
| $c^1$ | 562 | 281.0 | | | |
| f | 831 | 277.3 | | | |
| c | 1014 | 253.5 | c | 608 | 304.0 |
| F | 1209 | 201.7 | F | 783 | 261.3 |
| C | 1321 | 165.1 | C | 914 | 228.5 |
| FF | 1459 | 121.7 | FF | 1106 | 184.5 |

Description:

The instrument has been restored at least twice: in 1918 by Arnold Dolmetsch, and in 1976 by Christopher Clarke. The stand and the baseboard probably date from the earlier of the two restorations. Repairs to the soundboard were carried out by Christopher Clarke.

The outer case and lid are painted in simulation of tortoise-shell, and the interior of the lid is lacquered red with chinoiserie in gold and black. The nameboard and keywell cheeks are veneered in vertical-grained olive wood, and the soundboard is painted with flowers.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.64, as No.17., where the date given incorrectly as 1763. Technical drawing by Christopher Clarke and John Barnes.

Former owners:

Isambard Kingdom Brunel, and later Sir Humphrey Noble, Bt.

**1762 JH**

**Johann Adolph Hass, 1762 unfretted Clavichord**

Forsyth Collection, Manchester

Signature: no longer legible

Case dimensions:

Length 1736, with baseboard mouldings 1758, inside length 1701

Width 536, with baseboard mouldings 548, inside width 501

Right-hand case front 765½

Height of case sides 138, with baseboard 168

Keywell length 844

Keyboard:

Compass FF to $f^3$, 61 notes

4ft strings from FF to B

Length of top key 480, bottom key 426½

Three-octave span 492

Total width of keys at keyfronts 844

Naturals of ivory

Sharps of black-stained lime topped with a plate of ebony

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 105 | 280.3 | | | |
| $c^3$ | 142 | 282.0 | | | |
| $f^2$ | 211 | 281.7 | | | |
| $c^2$ | 287½ | 287.5 | | | |
| $f^1$ | 423 | 282.3 | | | |
| $c^1$ | 564½ | 282.3 | | | |
| f | 830 | 277.0 | | | |
| c | 1023 | 255.8 | B | 627 | 296.0 |
| F | 1210 | 201.9 | F | 783 | 261.3 |
| C | 1324 | 165.5 | C | 919 | 229.8 |
| FF | 1470 | 122.6 | FF | 1121 | 187.0 |

Description:

The instrument is in a very sorry state. The soundboard, for instance, is very dirty and badly cracked in several places, and the two planks of the baseboard have split apart. At some point in the instrument's history an attempt has been made to repair the soundboard with three or four crude dowels. The outside of the case and the lid is an overpainting of the original. The instrument sits on a later stand.

The inside of the lid is lacquered red, and decorated with chinoiserie in gold and black in the same style as the lid decoration on the 1761c JH, the 1763a JH and the 1763b JH. Contrary to Boalch the date 1762 is not written on the interior of the lid.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.14b. Part of the lid is illustrated in A. Conradt, "Hamburger Musikinstrumente des 18. Jahrhunderts mit lackmalerei," *Jahrbuch der Hamburger Kunstsammlungen*, IX (1964), p.46.

**1763a JH**

**Johann Adolph Hass, 1763 unfretted Clavichord**

Russell Collection, University of Edinburgh, Cat. No.22

Signature: "J. A. Hass / Hambg Anno 1763"

Case dimensions:

- Length 1730, with baseboard mouldings 1750, inside length 1694
- Width 535, with baseboard mouldings 551, inside width 497½
- Right-hand case front 760
- Height of case sides 140, with baseboard 170
- Keywell length 847

Keyboard:

- Compass FF to $f^3$, 61 notes
- 4ft strings from FF to B
- Length of top key 475, bottom key 419
- Three-octave span 490
- Total width of keys at keyfronts 840
- Naturals of tortoise-shell
- Sharps of black-stained lime topped with a plate of mother-of-pearl
- Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 103 | 275.0 | | | |
| $c^3$ | 140 | 280.0 | | | |
| $f^2$ | 211 | 281.7 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 426 | 284.3 | | | |
| $c^1$ | 569 | 284.5 | | | |
| f | 838 | 279.6 | | | |
| c | 1023 | 255.8 | B | 625 | 295.0 |
| F | 1215 | 202.7 | F | 782 | 261.0 |
| C | 1323 | 165.4 | C | 914 | 228.5 |
| FF | 1473 | 122.9 | FF | 1116 | 186.2 |

Description:

The decoration of this instrument is particularly stunning. The outer case and lid are lacquered red and decorated with chinoiserie in gold and black, the name-board and keywell cheeks are veneered in olive wood, and the 4ft wrestplank and rack are veneered in Kingwood. A river scene, painted in oils, covers the interior of the lid. The oak toolbox lid is veneered in olive wood with a central engraved panel of mother-of-pearl. For an illustration of the toolbox lid see figure 7.8, p.231.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.15. Recorded by C. Napier in *A Brief Guide to the Russell Collection of Harpsichords and Clavichords* (Edinburgh: Rank Xerox, 1986), pp.16-7, as No.22. For a few measurements and an illustration see P. Williams and S. Newman, *The Russell Collection of Early Keyboard Instruments* (Edinburgh: Edinburgh University Press, 1968), pp.48-9. Illustrated in *The New Grove Dictionary of Music and Musicians*, ed. S. Sadie, vol.4 (London: MacMillan, 1981), p.465. Technical drawing by Richard Loucks (1974). Illustrated in M. Campbell and C. Greated, *The Musician's Guide to Acoustics* (London: Dent, 1987), pp.234 & 235.

Discography:

The instrument can be heard in a recording of Mozart's Fugue in g minor (K.375e, formerly K.401) by Peter Williams and Lucy Carolan (SCH 801).

Former owners:

Lord Dartmouth, Capt. Lane-Wanstead, and Raymond Russell (1956).

**1763b JH**

**Johann Adolph Hass, 1763 unfretted Clavichord**

Private ownership, Venice

Signature: "J. A. Hass / Hambg Anno 1763"

Case dimensions:

Length 1738, with baseboard mouldings 1760, inside length 1707

Width 529, with baseboard mouldings 544, inside width 499

Right-hand case front 770

Height of case sides 137½, with baseboard 168

Keywell length 849

Keyboard:

Compass FF to $f^3$, 61 notes

4ft strings from FF to B

Length of top key 475, bottom key 421½

Three-octave span 492

Total width of keys at keyfronts 845

Naturals of ivory

Sharps of black-stained lime topped with a plate of ebony

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 103 | 275.0 | | | |
| $c^3$ | 139 | 278.0 | | | |
| $f^2$ | 212 | 283.0 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 423 | 282.3 | | | |
| $c^1$ | 566 | 283.0 | | | |
| f | 834 | 278.3 | | | |
| c | 1017 | 254.3 | B | 628 | 296.4 |
| F | 1215 | 202.7 | F | 782 | 261.0 |
| C | 1327 | 165.9 | C | 914 | 228.5 |
| FF | 1478 | 123.3 | FF | 1123 | 187.4 |

Description:

The decoration of this instrument is exactly the same as the 1761c JH. The outer case is painted in simulation of tortoise-shell, and the interior of the lid is lacquered red and decorated with chinoiserie in gold and black.

The instrument was restored by Arnold Dolmetsch in 1895, who made the present square tapered legs. It is interesting to note that between 1894 and 1896 Arnold Dolmetsch made a series of six large clavichords. Although these are said to be copies of a clavichord inscribed: "S[oli] D[eo] G[loria] Christian Gotthelf Hoffmann in Ronneburg. Nom: 1784" they are very similar to the clavichords of Hass. Since Dolmetsch must have had access to the 1763b JH during this period, he may well have based his design in part on the large FF to $f^3$ clavichords of Hass.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.63, as No.16. Illustrated and described in Sotheby's catalogue for Thursday 12th December 1985, No.110.

Former owners:

Gerald Wellesley, Messrs Legg of Cirencester (1935), Captain Lane, Hugh Gough (1945-7), Michael Thomas (1954), and Vere Pilkington (Portugal, 1966).

**1767 JH**

**Johann Adolph Hass, 1767 unfretted Clavichord**

Private ownership, London

Signature: "J. A. Hass / Hambg Anno 1767"

Case dimensions:

Length 1738, with baseboard mouldings 1755, inside length 1703
Width 537, with baseboard mouldings 548, inside width 504
Right-hand case front 770
Height of case sides 151, with baseboard 180
Keywell length 843

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to c
Length of top key 479, bottom key 422
Average three-octave span 490
Total width of keys at keyfronts 841½
Naturals of tortoise-shell
Sharps of black-stained lime topped with a chevron plate of mother-of-pearl and tortoise-shell
Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 103 | 275.0 | | | |
| $c^3$ | 140 | 280.0 | | | |
| $f^2$ | 215 | 287.0 | | | |
| $c^2$ | 287 | 287.0 | | | |
| $f^1$ | 423 | 282.3 | | | |
| $c^1$ | 567 | 283.5 | | | |
| f | 850 | 283.7 | | | |
| c | 1043 | 260.8 | c | 597 | 298.5 |
| F | 1238 | 206.6 | F | 778 | 259.6 |
| C | 1347 | 168.4 | C | 915 | 228.8 |
| FF | 1489 | 124.2 | FF | 1128 | 188.2 |

Description:

The outer case and lid are painted brown with imitation wood graining, and the interior of the lid is decorated with a landscape painting. For an illustration of the toolbox lid see figure 7.9, p.232. The use of red ink for the signature, gauge numbers and note-letter names on the soundboard is atypical of Hass.

A unique feature of this clavichord is the spruce board beneath the keylevers. Since the quality of the workmanship is of the same high standard as the rest of the instrument the board is original. Although it is unknown for what purpose this board was originally designed it cannot be an extra soundboard because there is no contact between the board and the strings.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.64, as No.19. Illustrated in R. Russell, *The Harpsichord and Clavichord* (London: Faber, 1973), plates 93 and 94. Illustrated and described in Sotheby's catalogue for 7th April 1983.

Former owners:

Sir Gervas Glyn, Bt., Margaret Glyn, and Raymond Russell (1952). The clavichord was sold at Sotheby's on April 7th, 1983 on behalf of the Rothschild Trust Company Ltd.

## SELECT CATALOGUE OF HASS HARPSICHORDS

**1721 HH**

**Hieronymus Hass, 1721 double-manual harpsichord**

Göteborgs Historiska Museum, inv. no. 1456

Signature: "H. A. Hass fecit in Hamburg 1721"

Case dimensions:

Length 2582½

Width 977, inside width 945

Right-hand cheek 851½

Height of case sides average 240, with baseboard 254

Keywell length 945, distance between keyblocks 824

Keyboard:

Compass FF to $d^3$

Three-octave span 507½

Total width of keys at keyfronts 821

Naturals of tortoise-shell

Sharps of unstained lime topped with a plate of ivory

Arcades missing

Disposition:

3 x 8ft, 2 x 4ft

String scalings:

It is not possible to measure these because the nuts have been removed.

Description:

This harpsichord has been converted into a single-manual piano. In order to do this the upper manual of the harpsichord has been removed, together with most of the action. Some of the original jacks have been retained, however, as part of the damping mechanism of the piano.

What little evidence remains suggests that the disposition of this instrument is unique. There are two original bridges. One (for the 8ft strings) has three sets of original bridge pins, and one (for the 4ft strings) has two sets of bridge-pin holes. Although none of the 4ft bridge pins, 4ft hitchpins or 4ft tuning pins survive, I believe that the harpsichord was therefore originally provided with two sets of 4ft strings. The holes in the 4ft bridge are widely- and narrowly-spaced as for a normal 2 x 8ft spacing, and there is a double-scribed line for the 4ft hitchpins.

Except for the vermilion on the spine of the harpsichord the outer case has been painted brown with imitation wood graining. The lid interior is decorated with raised chinoiserie on a red lacquer ground.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.2.

**1723 HH**

**Hieronymus Albrecht Hass, 1723 double-manual harpsichord**

Musikhistoriska Museet, Copenhagen, inv. no. A 48

Signature: "Hieronymus Albrecht Hasch : in Hambg / Anno 1723"

Case dimensions:

- Length 2372
- Width 951, inside width 920
- Right-hand cheek 748
- Height of case sides average 245, with baseboard $260\frac{1}{2}$
- Keywell length 920, distance between keyblocks 798

Keyboard:

- Compass FF to $c^3$
- Three-octave span $499\frac{1}{2}$
- Total width of keys at keyfronts 786
- Width of string band, top to bottom long 8ft string at nut 811
- Width of rack, top to bottom slots 801
- Naturals of red-stained tortoise-shell
- Sharps of unstained lime topped with a plate of ivory
- Arcades of incised white paper on red-stained background

Disposition:

3 x 8ft, 1 x 4ft

Buff stop works on the set of 8ft strings which are positioned on the lower section of the 8ft nut

Plucking direction:

| | | | |
|---|---|---|---|
| 8ft | <--- | Shorter long string on lower section of 8ft nut | |
| 8ft | ---> | Normal short string on rear, upper section of 8ft nut | (lower manual) |
| 4ft | ---> | Normal 4ft string (dogleg not original) | |
| ------ | ------ | ------------------------------------------------ | |
| 8ft | <--- | Longer 8ft string on rear, upper section of 8ft nut | (upper manual) |

String scalings:

| | 8ft Strings | | | | 4ft Strings |
|---|---|---|---|---|---|
| | long | middle | short | | |
| $c^3$ | 191½ | 182 | 179 | $c^3$ | 86 |
| $f^2$ | 282 | 273 | 269½ | $f^2$ | 136 |
| $c^2$ | 366½ | 358 | 350 | $c^2$ | 180 |
| $f^1$ | 524 | 513 | 502 | $f^1$ | 265 |
| $c^1$ | 680 | 668 | 649 | $c^1$ | 353 |
| f | 958 | 944 | 922 | f | 524 |
| c | 1169 | 1157 | 1133 | c | 666 |
| F | 1463 | 1450 | 1429 | F | 876 |
| C | 1613 | 1602 | 1593 | C | 1035 |
| FF | 1766 | 1752 | 1750 | FF | 1255 |

Gauge Numbers:

8ft jacks: FF to FF# N 000, GG to GG# N 00, AA to $BB^b$ N 0, BB to C# N 1, D to E N 2, F to F# N 3, G to A N 4, $B^b$ to d N 5, $e^b$ to g N 6, g# to $d^1$ N 7, $e^{b1}$ to $c^2$ N 8, $c^{\#2}$ to $c^3$ N 9.

4ft jacks: FF to FF# N 2, GG to AA N 3, $BB^b$ to C N 4, C# to $E^b$ N 5, E to G N 6, G# to d N 7, $e^{b1}$ to $d^1$ N 8, , $e^{b1}$ to $c^2$, $d^2$ and $e^2$ N 9, $c^{\#2}$, $e^{b2}$ and $f^2$ to $c^3$ N 10.

Description:

This is the only known instrument by Hass on which he signs his name 'Hasch.' There is no indication, however, to suggest that Hieronymus Hass was not the original maker.

The layout of this harpsichord is very unusual. Due to the presence of three choirs of 8ft strings the 8ft nut is stepped. Two sets of 8ft strings (the set of longer 8ft strings and the set of normal short 8ft strings) are positioned on the upper section of the 8ft nut, and an 'extra' set of 8ft strings is positioned on the lower section of the nut and passes through it to the tuning pins. The 'extra' course of 8ft strings has scalings which are intermediate to the two sets of 8ft strings on the upper section of the 8ft nut.

The two manuals can be coupled together by pushing in the upper manual. They can also be locked in either a coupled or an uncoupled position.

The outer case and lid are lacquered a dark green and decorated with raised chinoiserie in gold, red, brown and green. The lid interior is derived from an engraving by Bernard Picart, entitled the 'Grand Concert dans un Jardin,' which was made in Paris in 1709. The trestle stand with four turned legs is not original.

Former owner:

The harpsichord had been at Aalholm castle since about 1730, the family home of the Raben-Levetzan's. It was acquired by the Museum in 1931.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.3.

**17(2)6 HH**

**Hieronymus Albrecht Hass, 17(2)6 Single-manual harpsichord**

Leuvsta Bruk Manor House, Sweden.

Signature: "H A Hass Fecit / 17 in Hamburg (2)6"

Case dimensions:

Length 2258

Width 849, inside width 877

Right-hand cheek 620½

Height of case sides average 188, with baseboard 102

Keywell length 848, distance between keyblocks 834

Keyboard:

Compass FF to $d^3$, extended to $f^3$

Three-octave span 485

Total width of keys at keyfronts

Width of string band, top to bottom long 8ft string at nut 802

Naturals of ivory

Sharps of black-stained lime topped with a plate of ebony

Guide tongues of brass

Arcades of embossed paper, with the initials "PLH" (those of Lindholm)

Disposition:

1 x 8ft, 1 x 4ft

Buff stop works on the set of 8ft strings

Plucking direction:

8ft <---

4ft --->

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 165 | 370.4 | $d^3$ | 76 | 341.2 |
| $c^3$ | 185 | 370.0 | $c^3$ | 85 | 340.0 |
| $f^2$ | 278 | 371.1 | $f^2$ | 126 | 336.4 |
| $c^2$ | 364 | 364.0 | $c^2$ | 169 | 338.0 |
| $f^1$ | 528 | 352.4 | $f^1$ | 254 | 339.0 |
| $c^1$ | 693 | 346.5 | $c^1$ | 345 | 345.0 |
| f | 983 | 328.0 | f | 512 | 341.7 |
| c | 1202 | 300.5 | c | 651 | 325.7 |
| F | 1502 | 250.6 | F | 859 | 286.7 |
| C | 1660 | 207.5 | C | 1010 | 252.5 |
| FF | 1786 | 149.0 | FF | 1205 | 201.1 |

Gauge numbers:

8ft jacks: FF to GG N 00, GG# to BB N 0, C to C# N 1, D to E N 2, F to G N 3, G # to B N 4, c to d N 5, $e^b$ to g N 6, g# to $e^1$ N 7, $f^1$ to $e^{b2}$ N 8, $e^2$ to $d^3$ N 9.

4ft jacks: FF to FF# N 2, GG to A N 3, $BB^b$ to C# N 4, D to E N 5, F to A N 6, $B^b$ to e N 7, f to d N 8, $e^b$ to $d^3$ N 9.

Description:

The disposition of this harpsichord (1 x 8ft, 1 x 4ft) is more typical of sixteenth-century Italian and seventeenth-century Flemish harpsichords than those built in the eighteenth century. It is worth pointing out, however, that the harpsichord built in Hamburg in 1710 by Johann Fleischer II (and now at the Musikinstrumentenmuseum, Berlin, inventory number 5083) originally had this disposition.

Apart from a petit ravalement at the end of the end of the eighteenth century by Lindholm the 17(2)6 HH is in a basically original state. The painted soundboard is in mint condition, and many of the jacks retain their eighteenth-century dampers. The instrument even retains its original music desk.

Literature:

There are no references to this instrument in the literature.

**1732a HH**

**Hieronymus Albrecht Hass, 1732 Single-manual harpsichord**

Kunstindustrimuseet, Oslo, inventory number 10780

Signature: "Hieronymus Albrecht Hass fecit / Hamburg Anno 1732"

Case dimensions:

Length 2096

Width 835, inside width 802

Right-hand cheek 644

Height of case sides average 225, with baseboard $239\frac{1}{2}$

Keywell length 802, distance between keyblocks 716

Keyboard:

Compass C to $d^3$

Three-octave span 494

Total width of keys at keyfronts 706, 30 naturals

Width of string band, top to bottom long 8ft string at nut 703

Width of rack, top to bottom slots C-$d^3$ 698

Naturals of ivory

Sharps of black-stained lime topped with a plate of ebony

Arcades of incised paper on a red background

Disposition:

2 x 8ft, 1 x 4ft

Buff stop works on the shorter set of 8ft strings

Plucking direction:

4ft <---

8ft <--- Long string

8ft ---> Short string

String scalings:

| | Long 8ft | Short 8ft | 4ft |
|---|---|---|---|
| $d^3$ | 166 | 160 | 76 |
| $c^3$ | 183 | 175 | 85 |
| $f^2$ | 273 | 259 | 127 |
| $c^2$ | 361 | 345 | 172 |
| $f^1$ | 531½ | 507 | 261 |
| $c^1$ | 695 | 664 | 348 |
| f | 981 | 944½ | 410½ |
| c | 1203 | 1166 | 645 |
| F | 1508 | 1478 | 838 |
| C | 1617 | 1608 | 970 |

Description:

This is one of the most splendidly-decorated instruments to survive from the Hass workshops. For an illustration of the harpsichord see plate 7.2, p.206. It is perhaps because of its beautiful decoration that this is one of the best preserved instruments of Hass. Except for the jacks (which are modern replacements) all the action parts of the harpsichord are original and in very good condition.

Former owner:

The harpsichord was acquired by the Museum in 1895 from the Lorange family of Spφrck-garden in Frederiskshald, Denmark

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.4.

**1734 HH**

**Hieronymus Albrecht Hass, 1734 Double-manual harpsichord**

Brussels Conservatoire, catalogue number M.630

Signature: "Hieronymus Albre Hass. fecit. / Hamburg Anno 1734"

Case dimensions:

Length 2672, with baseboard moulding 2690
Width 926, inside width 891
Right-hand cheek length 990
Height of case sides average 255, with baseboard $269\frac{1}{2}$
Keywell length 890, distance between keyblocks average 788

Keyboard:

Compass GG to $d^3$
Three-octave span 495
Total width of keys at keyfronts 783, 35 naturals
Width of string band, top to bottom long 8ft string at nut 795
Naturals of ivory
Sharps of black-stained lime topped with a chevron plate
of ivory and tortoise-shell
Arcades of ebony

Disposition:

1 x 16ft, 2 x 8ft, 1 x 4ft

Buff stop works on the set of 16ft strings and on the shorter set of 8ft strings

Plucking direction:

| | | | |
|---|---|---|---|
| 16ft | ---> | | |
| 8ft | ---> | Short string | (lower manual) |
| 4ft | <--- | | |
| ----------------------------------- | | | |
| 8ft | <--- | Long string (dogleg) | (upper manual) |
| 8ft | <--- | Close-plucking lute on long string | |

String scalings:

| | 16ft | Long 8ft | 4ft |
|---|---|---|---|
| $d^3$ | 214 | 166 | 78 |
| $c^3$ | 379 | 185 | 88 |
| $f^2$ | 546 | 271 | 130 |
| $c^2$ | 707 | 359 | 173 |
| $f^1$ | 998 | 530 | 259 |
| $c^1$ | 1229 | 693½ | 344 |
| f | 1559 | 964 | 515 |
| c | 1786 | 1172 | 661 |
| F | 1968 | 1465 | 877 |
| C | 2046 | 1625 | 1033 |
| GG | 2115 | 1741½ | 1178 |

Description:

The interior of the lid has an oil painting which depicts the 'Trojan horse.' The instrument is supported by its original baluster stand. Unfortunately the decoration on the stand and on the exterior of the case and lid appears to be an over-painting, since there are traces of an earlier (perhaps original) vermilion-coloured pigment underneath. The legs of the stand appear to have been turned from Scots pine.

The instrument was restored in the middle of the nineteenth century by Fleury. A nameplaque fixed to the treble keyblock of the upper manual reads: "Restauré par Fleury facteur de pianos à Paris en 1858."

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.62, as No.5. Illustrated in J. Montagu, *The World of Baroque and Classical Musical Instruments* (Newton Abbot: David and Charles, 1979), p.68. Also illustrated in R. Russell, *The Harpsichord and Clavichord*, 2nd rev. ed. (London: Faber and Faber, 1973), plate 85.

**1764 JH**

**Johann Hass, 1764 single-manual harpsichord**

Russell Collection, Edinburgh, Cat. No.14

Signature: "J. A. Hass / Hambg Anno`1764"

Case dimensions:

Length 2302

Width 976½, inside width 939

Right-hand cheek 660

Height of case sides average 233, with baseboard 245

Keywell length 941, distance between keyblocks 851

Keyboard:

Compass FF to $f^3$, 61 notes

Three-octave span 492

Total width of keys at keyfronts 844

Width of string band, top to bottom long 8ft string at nut 822

Width of rack, top to bottom slots 824

Naturals of ivory, the natural heads are not original

Sharps of black-stained lime topped with a plate of ebony

Arcades of ebony

Disposition:

2 x 8ft, 1 x 4ft

Buff stop works on the shorter set of 8ft strings

Plucking direction:

| | | |
|---|---|---|
| 8ft | <--- | Long string |
| 4ft | <--- | |
| 8ft | ---> | Short string |

String scalings:

| | Long 8ft | Short 8ft | 4ft |
|---|---|---|---|
| $f^3$ | 141 | 135 | 66½ |
| $c^3$ | 183½ | 176 | 89 |
| $f^2$ | 272 | 259 | 129 |
| $c^2$ | 362½ | 347 | 172½ |
| $f^1$ | 532½ | 512 | 258 |
| $c^1$ | 694½ | 667½ | 350½ |
| f | 975 | 944 | 522 |
| c | 1184 | 1153 | 650 |
| F | 1483 | 1450 | 859 |
| C | 1675 | 1650½ | 1003 |
| FF | 1819 | 1808 | 1212 |

Description:

Unlike the other single-manual Hass harpsichord with a dispositon of 2 x 8ft, 1 x 4ft, the two 8ft registers of this instrument are separated by the 4ft register. This arrangement, typical of eighteenth-century French harpsichords, accentuates the tonal contrast between the two 8ft registers.

The present outer-case mahogany veneer is not original, and may date from the time of the harpsichord's restoration by Erard in 1935. Only the rosewood veneer on the namebatten and on the keyblocks is original since it is similar to the veneer used on the 1763a JH clavichord. The original outer-case decoration (in imitation tortoise-shell) is, however, still visible behind the nameboard.

Former owners:

C. J. Reinhold of Amsterdam (1867), various members of the Six family of Amsterdam, Mary Dunne of California, and Raymond Russell (1955).

Literature:

Brief catalogue entry in S. Newman and P. Williams, *The Russell Collection and other Early Keyboard Instruments in Saint Cecilia's Hall, Edinburgh* (Edinburgh: Edinburgh University Press, 1968), Cat. No.14, p.31.

## SELECT CATALOGUE OF CLAVICHORDS BY OTHER MEMBERS OF THE NORTH-GERMANIC TRADITION

### 1722 JF

**Johann Christoph Fleischer, 1722 fretted Clavichord**

Nydahl Collection, Stiftelsen Musikkulturens Framjande, Stockholm, number KL 46

Signature: "Johann Christoph Fleischer / Auxit Hamb Anno 1722"

Case dimensions:

- Length 1475½, with mouldings 1494, inside length 1449
- Width 430, with mouldings 440, inside width 402
- Right-hand case front 656
- Soundboard to top of case 36½
- Height of case sides 123, with baseboard 145
- Keywell length 689

Keyboard:

- Compass C to $c^3$, 49 notes
- Three-octave span 489
- Total width of keys at keyfronts 687
- Naturals of ivory
- Sharps of black-stained lime topped with a chevron plate of ivory and tortoise-shell
- Arcades of embossed parchment, green and gilt

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $c^3$ | 130 | 260.0 | | | |
| $f^2$ | 213 | 284.3 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 430 | 287.0 | | | |
| $c^1$ | 584½ | 292.3 | | | |
| f | 819 | 273.3 | d | 544 | 305.3 |
| c | 971 | 242.8 | c | 584 | 292.0 |
| F | 1151 | 192.1 | F | 810 | 270.3 |
| C | 1266 | 158.3 | C | 960 | 240.0 |

Fretting:

Unfretted from C to d and then fretted in pairs from $e^b$ upwards apart from the a's and the d's which are free. The pair $a^2$-$b^{b2}$ are also fretted together.

Description:

This is the earliest known Hamburg-made clavichord, and the earliest dated clavichord with a set of 4ft strings in the bass. Unfortunately the instrument has been re-decorated very badly. Traces of the original vermilion are visible beneath the thick coat of dark-green paint on the sides of the case and on the lid, and a large sheet of blue-coloured glass paper has been glued to the inside of the lid. The painted flowers on the soundboard have also been retouched.

Literature:

There are no references to this instrument in the literature.

**1723 JF**

**Johann Christoph Fleischer, 1723 Unfretted Clavichord**

Drottningholm Teatermuseum, Stockholm.

Signature: "Johan Christoph Fleischer / Fe : Hamburg Anº 1723"

Case dimensions:

- Length 1665, with mouldings 1686, inside length 1638
- Width 487, with mouldings 495, inside width 460
- Right-hand case front 732
- Height of case sides 141, with baseboard 162½
- Keywell length 800

Keyboard:

- Compass FF to $d^3$, 58 notes
- Three-octave span 492
- Total width of keys at keyfronts 797½, 34 naturals
- Naturals of tortoise-shell
- Sharps of black-stained lime topped with a plate of ivory which has been inlaid with tortoise-shell
- Arcades of ivory

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $d^3$ | 116 | 260.4 | | | |
| $c^3$ | 137½ | 275.0 | | | |
| $f^2$ | 217 | 289.7 | | | |
| $c^2$ | 285 | 285.0 | | | |
| $f^1$ | 408 | 272.3 | | | |
| $c^1$ | 537 | 268.5 | | | |
| f | 804 | 268.3 | d | 574 | 322.1 |
| c | 980 | 245.0 | c | 606½ | 303.3 |
| F | 1165 | 194.4 | F | 764 | 255.0 |
| C | 1290 | 161.3 | C | 920 | 230.0 |
| FF | 1451 | 121.1 | FF | 1117 | 186.4 |

Fretting:

This clavichord is unfretted, but uses the same rack-slot spacing pattern as the two fretted C to $c^3$ instruments examined.

Description:

The nameboard, toolbox lid and keywell faces are sumptuously decorated with ivory and tortoise-shell veneer. In addition to painted flowers the soundboard is decorated with a complicated fretwork design in the front left-hand corner. Although there is nothing to suggest that the fretwork design is a later addition, the outer case and lid were re-painted at the end of the nineteenth century. The painting on the outside of the lid is signed: "J K G 1895 / Efter gravyr af Boucher;" and the underside of the top keylever is signed in pencil: Måladt o renoveradt [painted and restored] 1895 af Otto Edman Stockholm."

Literature:

There are no references to this instrument in the literature.

**1728 JF**

**Johann Christoph Fleischer, 1728 Fretted Clavichord**

Ringve Museum, Trondheim RMT 386

Signature: "Johann Christoph Fleischer / ............... 1728"

Case dimensions:

Length 1478, with mouldings 1493, inside length 1448

Width 429, with mouldings 440, inside width 400

Right-hand case front 661

Soundboard to top of case 40.2

Height of case sides 125, with baseboard 138½

Keywell length 687

Keyboard:

Compass C to $c^3$, 49 notes

Three-octave span 489

Total width of keys at keyfronts 682½, 29 naturals

Naturals of ivory

Sharps of black-stained lime topped with a chevron plate of ivory and tortoise-shell

Arcades of embossed parchment, green and gilt

String scalings:

| | 8ft Strings | |
|---|---|---|
| | Length | $c^2$ equivalent |
| $c^3$ | 125 | 250.0 |
| $f^2$ | 210 | 280.3 |
| $c^2$ | 288 | 288.0 |
| $f^1$ | 457 | 305.0 |
| $c^1$ | 608 | 304.0 |
| f | 828 | 276.3 |
| c | 971 | 242.8 |
| F | 1144 | 190.9 |
| C | 1255 | 156.9 |

Fretting:

Unfretted from C to d and then fretted in pairs from $e^b$ upwards, apart from the a's and the d's which are free. The pair $a^2$-$b^{b2}$ are also fretted together.

Description:

It is interesting to note that this instrument is simply bi-chord strung throughout, and does not have the usual 4ft strings in the bass. Apart from the lack of 4ft strings in the bass, however, the instrument is clearly of the same design as the 1722 JF. The compass and the case dimensions are the same, and a comparison of rubbings made of the tops of the 8ft bridge pins and of the positions of the rack slots has revealed that the 1722 JF and the 1728 JF have identical 8ft bridges and identical racks.

Literature:

There are no references to this instrument in the literature.

**1756 JG**

**Johann Christoph Gerlach, 1756 Unfretted Clavichord**

Ringve Museum, Trondheim, RMT 74/15

Signature: "J C Gerlach Hamburg 1756"

Case dimensions:

Length 1700.5, with mouldings 1726, inside length 1670
Width 523½, with mouldings 535, inside width 493
Right-hand case front 733
Soundboard to top of case 35½ to 36
Height of case sides 129, with baseboard 161
Keywell length 844

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to d
Three-octave span 489
Total width of keys at keyfronts
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades identified by Grant O'Brien as of palisander

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 108 | 288.3 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 214 | 285.7 | | | |
| $c^2$ | 289 | 289.0 | | | |
| $f^1$ | 436 | 291.0 | | | |
| $c^1$ | 578 | 289.0 | | | |
| f | 833 | 278.0 | d | 595 | 334.0 |
| c | 1019 | 254.8 | c | 641 | 320.5 |
| F | 1209 | 201.7 | F | 803 | 268.0 |
| C | 1318 | 164.8 | C | 925 | 231.3 |
| FF | 1452 | 121.1 | FF | 1100 | 183.5 |

Gauge Numbers:

FF to GG 000, GG$^{\#}$ to BB 00, C to D 0, E$^{b}$ to F 1, F$^{\#}$ to A 2, B$^{b}$ to e 3, f to b 4, c$^{1}$ to b$^{1}$ 5, c$^{2}$ to f$^{3}$ 6

Description:

This is very similar to the clavichords built in the Hass workshops. The materials used by Gerlach in the construction of this instrument, together with the case joints and the general layout are all typical of the FF to f$^{3}$ clavichords of Hieronymus and Johann Hass. I have therefore used much of Grant O'Brien's analysis of this instrument to try and illuminate some of the practices of Hass.

Despite the fact that the original iron oxide paint is covered with a later over-painting this instrument is remarkable for its number of original features. For example there are the remains of old, possibly late eighteenth-century strings on the 4ft tuning pins, and the balance cloths and back touchrail cloth appear to be original. This means that this clavichord is one of the few instruments of the Hamburg School to retain its original depth of touch.

Literature:

Detailed analysis and photographs in G. O'Brien, "Catalogue Description: Unfretted Clavichord by I.C. Gerlach, Hamburg, 1756," held at Ringve Museum, Trondheim, with copies at the Russell Collection, (Edinburgh, 1990).

**1769 JG**

**Johann Christoph Gerlach, 1769 Unfretted Clavichord**

Museum für Hamburgische Geschichte, Hamburg

Signature: "J. C. Gerlach. Hamburg 1769"

Case dimensions:

Length 1701, with mouldings 1726, inside length 1669
Width 517, with mouldings 535, inside width 486½
Right-hand case front 744
Soundboard to top of case 36½
Height of case sides 133, with baseboard 163
Keywell length 840

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to c
Three-octave span 488
Total width of keys at keyfronts 833
Naturals of ivory
Sharps of black-stained lime topped with a plate of ebony
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 104 | 277.6 | | | |
| $c^3$ | 142 | 284.0 | | | |
| $f^2$ | 212 | 283.0 | | | |
| $c^2$ | 284 | 284.0 | | | |
| $f^1$ | 431 | 287.7 | | | |
| $c^1$ | 572 | 286.0 | | | |
| f | 822 | 274.3 | | | |
| c | 1008 | 252.0 | c | 620 | 310.0 |
| F | 1200 | 200.2 | F | 785 | 262.0 |
| C | 1310 | 163.8 | C | 910 | 227.5 |
| FF | 1447 | 120.7 | FF | 1088 | 181.5 |

Description:

The instrument is of the same model as the 1756 JG. Although it does not have any of the original features associated with the 1756 JG it is in good playing condition. As with many Hass clavichords it has been overpainted. The original vermilion on the outer case and lid, for example, is visible in several places beneath a thick layer of brown paint.

Literature:

There are no references to this instrument in the literature.

**1751 BF**

**Barthold Fritz, 1751 Unfretted Clavichord**

Victoria and Albert Museum, London, inventory number 339-1882

Signature: "Barthold Fritz fecit Braunschweig anno 1751 Mens. Febr."

Case dimensions:

- Length 1754½, with mouldings 1784, inside length 1726
- Width 543, with mouldings 575, inside width 517
- Right-hand case front 730
- Soundboard to top of case 35
- Height of case sides with baseboard 169
- Keywell length 894

Keyboard:

- Compass FF to $a^3$, 65 notes
- 4ft strings from FF to c
- Three-octave span 491
- Naturals of rosewood
- Sharps of black-stained wood topped with an engraved plate of ivory
- Arcades of embossed leather

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $a^3$ | 88 | 296.0 | | | |
| $f^3$ | 111 | 296.3 | | | |
| $c^3$ | 148 | 296.0 | | | |
| $f^2$ | 221 | 295.0 | | | |
| $c^2$ | 294 | 294.0 | | | |
| $f^1$ | 426 | 284.3 | | | |
| $c^1$ | 566 | 283.0 | | | |
| f | 834 | 278.3 | | | |
| c | 1017 | 254.3 | c | 652½ | 326.3 |
| F | 1219 | 203.4 | F | 810 | 270.3 |
| C | 1341½ | 167.7 | C | 926½ | 231.6 |
| FF | 1499 | 125.1 | FF | 1110 | 185.2 |

Gauge Numbers:

8ft gauge numbers: C# to D 0, $E^b$ to F 1, F# to A 2, $B^b$ to e 3, f to b 4, $c^1$ to $b^1$ 5, $c^2$ to $c^3$ 6, $c^{\#3}$ to $a^3$ 7.

4ft gauge numbers: FF to FF# 2, GG to BB 3, C to E 4, F to A 5, $B^b$ to B 6, c 7.

Description:

Although the original outer-case decoration is obscured by the present pale-green paintwork the painting on the interior of the lid is original. The lid painting (in Delft blue) depicts a stag hunt. The existence of gauge numbers on the key-levers for both the 8ft and the 4ft strings is important to the study of the Hamburg School of clavichord building, since Hamburg builders do not mark the 4ft gauge numbers.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.47, as No.2. Catalogue description and illustration in R. Russell, *Victoria and Albert Musuem. Catalogue of Musical Instruments. I. Keyboard Instruments* (London: H.M.S.O., 1968), Cat. No.28, pp.58-9. Description and illustration in H. Schott, *Victoria and Albert Musuem. Catalogue of Musical Instruments. I. Keyboard Instruments* (London: H.M.S.O., 1985), Cat. No.26, pp.78-80.

Former owner:

Carl Engel.

**1770 MM**

**Moritz Georg Moshack, 1770 unfretted clavichord**

Musikhistorisk Museum, Copenhagen, inventory number A36.

Signature: "Moritz Georg Moshack / in Copenhagen Aº 1770"

Case dimensions:

Length 1692, with mouldings 1713, inside length 1656

Width 510, with mouldings 520, inside width 476

Right-hand case front 730

Height of case sides 141, with baseboard 175

Keywell length 832

Keyboard:

Compass FF to $f^3$, 61 notes

4ft strings from FF to d

Three-octave span 483

Total width of keys at keyfronts 827

Naturals of ivory

Sharps of black-stained wood topped with a plate of ebony

Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 93 | 248.2 | | | |
| $c^3$ | 134 | 268.0 | | | |
| $f^2$ | 204 | 272.3 | | | |
| $c^2$ | 278 | 278.0 | | | |
| $f^1$ | 421 | 281.0 | | | |
| $c^1$ | 564 | 282.0 | | | |
| f | 814 | 271.6 | d | 583 | 327.2 |
| c | 976 | 244.0 | c | 630 | 315.0 |
| F | 1193 | 199.1 | F | 813 | 271.3 |
| C | 1308 | 163.5 | C | 922 | 230.5 |
| FF | 1450 | 121.0 | FF | 1111 | 185.4 |

Description:

If it were not signed and dated by Moshack this clavichord could well be mistaken for an instrument built in the Hass workshops. The size of the case, for example, is the virtually the same as the 1742a HH and the 1742b HH. Furthermore, the arcades and the brass strapwork hinges are typical of those found on Hass clavichords. Most remarkable, however, is the fact that the corner dovetail joints were marked out with a template with exactly the same size and spacing of the dovetails as found on the FF to $f^3$ clavichords of Hass. I have not seen the other surviving instruments of Moshack, but it seems very likely that Moshack was apprenticed to Hass, and made a copy of his dovetail template.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.115, as No.2.

Former owner:

Purchased by the Museum in 1922 from A. Madsen, Copenhagen.

**1796b DH**

**Dietrich Christoph Hass, 1796 unfretted Clavichord**

Museum für Kunst und Gewerbe, Hamburg, inventory number 1904.709

Signature: "Dietr. Chr. Hass Hamburg 1796"

Case dimensions:

Length 1732, with baseboard mouldings 1752, inside length 1705
Width 535, with baseboard mouldings 551½, inside width 508
Right-hand case front 764
Height of case sides 137, with baseboard 165½
Keywell length 839

Keyboard:

Compass FF to $f^3$, 61 notes
4ft strings from FF to d
Length of top key 483, bottom key 438
Three-octave span 491
Total width of keys at keyfronts
Naturals of ivory
Sharps of black-stained lime topped with a plate of of tortoise-shell
Arcades of ebony

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $f^3$ | 106 | 283.0 | | | |
| $c^3$ | 141 | 282.0 | | | |
| $f^2$ | 219 | 292.3 | | | |
| $c^2$ | 290 | 290.0 | | | |
| $f^1$ | 434½ | 290.0 | | | |
| $c^1$ | 570 | 285.0 | | | |
| f | 836 | 279.0 | d | 574 | 322.1 |
| c | 1010 | 252.5 | c | 621½ | 310.8 |
| F | 1203 | 200.7 | F | 797 | 266.0 |
| C | 1320 | 165.0 | C | 925 | 231.3 |
| FF | 1467 | 122.4 | FF | 1112 | 185.5 |

Description:

The Museum believes that Johann Hass was the original maker of this instrument and that Dietrich Hass restored it, replaced the soundboard and then signed the instrument as his own work. The clavichord does have a number of features common to the clavichords of Johann and Hieronmyus Hass, but so do many other instruments built in the North-Germanic tradition. As discussed in chapter 8, pp.247-8, it is more likely that Dietrich Hass was the original builder, and was perhaps apprenticed to Hieronymus or Johann Hass, or to Gerlach.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.64, as No.23. Recorded and illustrated in A. Pilipczuk, "Zur Restaurierung des Hass-Clavichords von 1732," *Das Musikinstrument* (1988), pp.46 and 48.

Former owner:

The instrument was acquired by the Museum in 1904 from the legacy of the Hamburg piano-maker Adolph Heinrich Emil Kohl (1847-1902).

**1796 GR**

**George Christoffer Rackwitz, 1796 unfretted Clavichord**

Russell Collection, Edinburgh, Cat. No.32; on loan from the Galpin Society

Signature: "NR 22 / af / G C Rackwitz / i / STOCKHOLM / 1796"

Case dimensions:

Length 2018, with baseboard mouldings 2022, inside length 1988

Width 592, with baseboard mouldings 596, inside width 552

Right-hand case front 954

Height of case sides 159, with baseboard 205

Keywell length 926

Keyboard:

Compass FF to $c^4$, 68 notes

4ft strings from FF to c

Length of top key 539, bottom key 415

Three-octave span 488

Total width of keys at keyfronts 923½

Naturals of ebony

Sharps of black-stained wood topped with plate of bone

Arcades of sycamore

String scalings:

| | 8ft Strings | | | 4ft Strings | |
|---|---|---|---|---|---|
| | Length | $c^2$ equivalent | | Length | $c^2$ equivalent |
| $c^4$ | 84 | 336.0 | | | |
| $f^3$ | 125 | 333.7 | | | |
| $c^3$ | 166 | 332.0 | | | |
| $f^2$ | 251 | 335.0 | | | |
| $c^2$ | 327 | 327.0 | | | |
| $f^1$ | 470 | 313.7 | | | |
| $c^1$ | 630 | 315.0 | | | |
| f | 933 | 311.4 | | | |
| c | 1151 | 287.8 | c | 619 | 309.5 |
| F | 1435 | 239.4 | F | 840 | 280.0 |
| C | 1575 | 196.9 | C | 1005 | 251.3 |
| FF | 1706 | 142.3 | FF | 1246 | 207.7 |

Description:

This is a typical Swedish clavichord from the end of the eighteenth century, and one which has a number of features atypical of the Hamburg School. The compass (FF to $c^4$) is larger than any surviving clavichord built in Hamburg, and the grain direction of the soundboard wood runs diagonally to the spine rather than being parallel to it. When expressed in millimetres the string scaling of $c^2$ scaling (327mm) is also much longer than the $c^2$ scaling of any Fleischer, Hass, or Gerlach clavichord. A $c^2$ scaling of 327mm is in fact suitable for iron stringing rather than for brass. However, when expressed in the local unit of measure the $c^2$ scaling of this instrument is the same as those of the Hamburg School. The $c^2$ scaling of Hamburg-built clavichords is 1 Hamburg Fuss long, and the $c^2$ scaling of the 1796 GR is 1 Stockholm Fot long. The discrepancy when expressed in millimetres is a result of a much larger foot measurement in use in Stockholm from that used in Hamburg.

Literature:

Recorded by D. Boalch in *Makers of the Harpsichord and Clavichord, 1440-1840*, 2nd ed. rev. (Oxford: Clarendon Press, 1974), p.124.

## Appendix 1:
## DETERMINATION OF THE MARKING OUT OF THE POSITION OF THE 8FT AND THE 4FT BRIDGE PINS

**Table A1.1a**
**Distance of the 8ft and 4ft bridge pins from the spine of the C to $d^3$ models**

**(1725) HH**

| | 8ft | 4ft |
|---|---|---|
| $c^{\#3}$-$d^3$ | 39 | |
| $b^2$-$c^3$ | 44 | |
| $a^2$-$b^{b2}$ | 49 | |
| $g^2$-$g^{\#2}$ | 53 | |
| $f^2$-$f^{\#2}$ | 58½ | |
| $e^{b2}$-$e^2$ | 63 | |
| $d^2$ | 69 | |
| $c^2$-$c^{\#2}$ | 75 | |
| $b^{b1}$-$b^1$ | 81 | |
| $a^1$ | 88 | |
| $g^1$-$g^{\#1}$ | 95 | |
| $f^1$-$f^{\#1}$ | 102 | |
| $e^{b1}$-$e^1$ | 109 | |
| $d^1$ | 117½ | |
| $c^1$-$c^{\#1}$ | 125 | |
| $b^b$-b | 134 | |
| a | 142 | |
| g-g# | 150 | |
| f-f# | 159 | |
| $e^b$-e | 169 | |
| d | 179 | -- |
| c# | 188 | 144 |
| c | 197 | 151 |
| B | 206 | 158 |
| $B^b$ | 214 | 167 |
| A | 223 | 176 |
| G# | 231 | 185 |
| G | 239 | 194 |
| F# | 247½ | 203 |
| F | 256 | 213 |
| E | 264½ | 223 |
| $E^b$ | 273 | 232 |
| D | 280½ | 242 |
| C# | 289½ | 252 |
| C | 299 | 261 |

**1740b HH**

| | 8ft | 4ft |
|---|---|---|
| $d^3$ | 34 | |
| $c^3$-$c^{\#3}$ | 38½ | |
| $b^{b2}$-$b^2$ | 43½ | |
| $a^2$ | 49 | |
| $g^2$-$g^{\#2}$ | 54 | |
| $f^2$-$f^{\#2}$ | 59½ | |
| $e^{b2}$-$e^2$ | 65 | |
| $d^2$ | 70 | |
| $c^2$-$c^{\#2}$ | 76 | |
| $b^{b1}$-$b^1$ | 82 | |
| $a^1$ | 89 | |
| $g^1$-$g^{\#1}$ | 95 | |
| $f^1$-$f^{\#1}$ | 102 | |
| $e^{b1}$-$e^1$ | 109 | |
| $d^1$ | 116 | |
| $c^1$-$c^{\#1}$ | 123 | |
| $b^b$-b | 132 | |
| a | 141 | |
| g-g# | 151 | |
| f-f# | 160 | |
| $e^b$-e | 169 | |
| d | 178 | 136 |
| c# | 188 | 144 |
| c | 197 | 152 |
| B | 206 | 160 |
| $B^b$ | 216 | 168 |
| A | 225 | 176½ |
| G# | 234 | 185 |
| G | 243 | 194 |
| F# | 252 | 203 |
| F | 261 | 212 |
| E | 270 | 222 |
| $E^b$ | 280 | 231 |
| D | 289 | 240 |
| C# | 298 | 249 |
| C | 307 | 259 |

**1761b JH**

| | 8ft | 4ft |
|---|---|---|
| $d^3$ | 36 | |
| $c^3$-$c^{\#3}$ | 40 | |
| $b^{b2}$-$b^2$ | 44½ | |
| $a^2$ | 49½ | |
| $g^2$-$g^{\#2}$ | 54 | |
| $f^2$-$f^{\#2}$ | 60½ | |
| $e^{b2}$-$e^2$ | 66 | |
| $d^2$ | 71 | |
| $c^2$-$c^{\#2}$ | 76½ | |
| $b^{b1}$-$b^1$ | 83 | |
| $a^1$ | 90 | |
| $g^1$-$g^{\#1}$ | 96 | |
| $f^1$-$f^{\#1}$ | 103 | |
| $e^{b1}$-$e^1$ | 109 | |
| $d^1$ | 116½ | |
| $c^1$-$c^{\#1}$ | 124 | |
| $b^b$-b | 134 | |
| a | 142 | |
| g-g# | 151½ | |
| f-f# | 161 | |
| e | 170 | |
| $e^b$ | 179 | |
| d | 188 | 146 |
| c# | 198 | 154 |
| c | 206½ | 162 |
| B | 216½ | 170 |
| $B^b$ | 226 | 178 |
| A | 236 | 186 |
| G# | 245 | 195 |
| G | 254 | 204 |
| F# | 263½ | 212½ |
| F | 272½ | 221½ |
| E | 281½ | 230 |
| $E^b$ | 290 | 239 |
| D | 300 | 248 |
| C# | 309 | 258 |
| C | 319 | 268 |

**Table A1.1b**
**Number of string pairs per Zoll for the C to $d^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

**(1725) HH**

| | 8ft | 4ft |
|---|---|---|
| $c^{\#3}$-$d^3$ | 7 in $1\frac{1}{2}$ | |
| $b^2$-$c^3$ | | |
| $a^2$-$b^{b2}$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 7 in $1\frac{1}{2}$ | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b1}$-$e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 20 in $7^3/_{11}$ | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b$-e | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 20 in $7^3/_{11}$ | 5 in 2 |

**1740b HH**

| | 8ft | 4ft |
|---|---|---|
| $d^3$ | 8 in $1\frac{1}{2}$ | |
| $c^3$-$c^{\#3}$ | | |
| $b^{b2}$-$b^2$ | | |
| $a^2$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 8 in $1\frac{1}{2}$ | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b1}$-$e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 20 in $7\frac{1}{2}$ | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b$-e | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 20 in $7\frac{1}{2}$ | 5 in 2 |

**1761b JH**

| | 8ft | 4ft |
|---|---|---|
| $d^3$ | 8 in $1^2/_3$ | |
| $c^3$-$c^{\#3}$ | | |
| $b^{b2}$-$b^2$ | | |
| $a^2$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 8 in $1^2/_3$ | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 21 in $8^1/_6$ | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| e | | |
| $e^b$ | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 21 in $8^1/_6$ | 5 in 2 |

## Table A1.1c
## Marking-out stick divisions for the C to $d^3$ models

### Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll

**(1725) HH**

| | 8ft | 4ft |
|---|---|---|
| $c^{\#3}$-$d^{3}$ | 14 in 3 | |
| $b^{2}$-$c^{3}$ | | |
| $a^{2}$-$b^{b2}$ | | |
| $g^{2}$-$g^{\#2}$ | | |
| $f^{2}$-$f^{\#2}$ | | |
| $e^{b2}$-$e^{2}$ | | |
| $d^{2}$ | 14 in 3 | |
| $c^{2}$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^{1}$ | | |
| $a^{1}$ | | |
| $g^{1}$-$g^{\#1}$ | | |
| $f^{1}$-$f^{\#1}$ | | |
| $e^{b1}$-$e^{1}$ | | |
| $d^{1}$ | 7 in 2 | |
| $c^{1}$-$c^{\#1}$ | 11 in 4 | |
| $b^{b}$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^{b}$-e | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^{b}$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^{b}$ | | |
| D | | |
| C# | | |
| C | 11 in 4 | 5 in 2 |

**1740b HH**

| | 8ft | 4ft |
|---|---|---|
| $d^{3}$ | 16 in 3 | |
| $c^{3}$-$c^{\#3}$ | | |
| $b^{b2}$-$b^{2}$ | | |
| $a^{2}$ | | |
| $g^{2}$-$g^{\#2}$ | | |
| $f^{2}$-$f^{\#2}$ | | |
| $e^{b2}$-$e^{2}$ | | |
| $d^{2}$ | 16 in 3 | |
| $c^{2}$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^{1}$ | | |
| $a^{1}$ | | |
| $g^{1}$-$g^{\#1}$ | | |
| $f^{1}$-$f^{\#1}$ | | |
| $e^{b1}$-$e^{1}$ | | |
| $d^{1}$ | 7 in 2 | |
| $c^{1}$-$c^{\#1}$ | 8 in 3 | |
| $b^{b}$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^{b}$-e | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^{b}$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^{b}$ | | |
| D | | |
| C# | | |
| C | 8 in 3 | 5 in 2 |

**1761b JH**

| | 8ft | 4ft |
|---|---|---|
| $d^{3}$ | 24 in 5 | |
| $c^{3}$-$c^{\#3}$ | | |
| $b^{b2}$-$b^{2}$ | | |
| $a^{2}$ | | |
| $g^{2}$-$g^{\#2}$ | | |
| $f^{2}$-$f^{\#2}$ | | |
| $e^{b2}$-$e^{2}$ | | |
| $d^{2}$ | 24 in 5 | |
| $c^{2}$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^{1}$ | | |
| $a^{1}$ | | |
| $g^{1}$-$g^{\#1}$ | | |
| $f^{1}$-$f^{\#1}$ | | |
| $e^{b2}$-$e^{2}$ | | |
| $d^{1}$ | 7 in 2 | |
| $c^{1}$-$c^{\#1}$ | 18 in 7 | |
| $b^{b}$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| e | | |
| $e^{b}$ | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^{b}$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^{b}$ | | |
| D | | |
| C# | | |
| C | 18 in 7 | 5 in 2 |

**Table A1.2a**
**Distance of the 8ft and 4ft bridge pins from the spine of the FF to $f^3$ models**

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $f^3$ | 35½ | | 34 | | 35 | | 39½ | |
| $e^3$ | 39 | | 38 | | 39 | | 43 | |
| $e^{b3}$ | 42 | | 41½ | | 42 | | 46 | |
| $d^3$ | 46 | | 45 | | 46 | | 50 | |
| $c^{\#3}$ | 50 | | 49 | | 50 | | 55½ | |
| $c^3$ | 55 | | 53 | | 55 | | 60 | |
| $b^2$ | 60 | | 58 | | 59 | | 64½ | |
| $b^{b2}$ | 65 | | 61½ | | 65 | | 69½ | |
| $a^2$ | 69 | | 66½ | | 69 | | 74 | |
| $g^{\#2}$ | 74 | | 71 | | 74 | | 79 | |
| $g^2$ | 79 | | 76 | | 79 | | 84½ | |
| $f^{\#2}$ | 84 | | 81 | | 84 | | 89 | |
| $f^2$ | 89 | | 85½ | | 88½ | | 93 | |
| $e^2$ | 93 | | 91 | | 93 | | 98½ | |
| $e^{b2}$ | 98 | | 96 | | 97½ | | 103 | |
| $d^2$ | 102½ | | 101 | | 102 | | 107½ | |
| $c^{\#2}$ | 107 | | 105 | | 107 | | 112½ | |
| $c^2$ | 112 | | 109 | | 112 | | 117½ | |
| $b^1$ | 117 | | 115 | | 117 | | 122 | |
| $b^{b1}$ | 122 | | 119 | | 122 | | 127 | |
| $a^1$ | 127 | | 124½ | | 127 | | 133 | |
| $g^{\#1}$ | 133 | | 129½ | | 132 | | 138 | |
| $g^1$ | 138 | | 134 | | 137½ | | 143 | |
| $f^{\#1}$ | 143½ | | 139½ | | 143 | | 148 | |
| $f^1$ | 149 | | 145 | | 149 | | 154 | |
| $e^1$ | 155 | | 151 | | 154½ | | 159½ | |
| $e^{b1}$ | 161½ | | 156 | | 160 | | 165½ | |
| $d^1$ | 167½ | | 161½ | | 166 | | 172 | |
| $c^{\#1}$ | 175 | | 167½ | | 172½ | | 178 | |
| $c^1$ | 181 | | 174 | | 179 | | 185 | |
| b | 188 | | 181 | | 186 | | 191½ | |
| $b^b$ | 194½ | | 187 | | 192½ | | 199 | |
| a | 201 | | 194 | | 200 | | 206 | |
| $g^\#$ | 208 | | 202 | | 206½ | | 213 | |
| g | 215 | | 209 | | 214 | | 220 | |
| $f^\#$ | 221½ | | 216½ | | 221 | | 227 | |
| f | 228½ | | 223 | | 228 | | 235 | |
| e | 235½ | | 231 | | 236 | | 242 | |
| $e^b$ | 242½ | | 238 | | 242½ | | 248½ | |
| d | 249 | 198½ | 246 | 195 | 250 | | 256½ | |
| $c^\#$ | 256 | 203 | 253 | 201½ | 257½ | | 263 | |
| c | 262½ | 208½ | 261 | 206 | 264½ | | 271 | 208½ |
| B | 269½ | 214 | 269 | 212 | 272 | 215½ | 277 | 216 |
| $B^b$ | 276 | 220 | 275 | 220 | 279½ | 222 | 284½ | 222½ |
| A | 283 | 225½ | 283 | 226 | 286 | 228½ | 292 | 228½ |
| $G^\#$ | 290½ | 231½ | 291 | 233 | 293 | 235½ | 299 | 235 |
| G | 297 | 238 | 298½ | 239 | 301 | 242 | 306 | 242 |
| $F^\#$ | 304½ | 244 | 306½ | 246 | 308 | 249½ | 313 | 249 |
| F | 311 | 251 | 313 | 254 | 315 | 257 | 321 | 257 |
| E | 319 | 258½ | 321 | 261 | 322 | 264 | 328½ | 264½ |
| $E^b$ | 326 | 265½ | 328 | 268 | 329½ | 272 | 335½ | 273 |
| D | 333 | 272½ | 336 | 277 | 337 | 279½ | 342 | 281 |
| $C^\#$ | 340 | 280 | 343 | 284½ | 344 | 287½ | 350 | 288 |
| C | 347 | 288 | 350½ | 292 | 351 | 295 | 357 | 296 |
| BB | 354 | 295½ | 357 | 300 | 361 | 303 | 368 | 305 |
| $BB^b$ | 361½ | 303 | 365 | 309 | 368½ | 311 | 376 | 313 |
| AA | 369 | 311 | 372 | 316 | 376 | 320 | 384 | 322 |
| $GG^\#$ | 376 | 318½ | 379 | 325 | 384 | 328 | 393 | 332 |
| GG | 383 | 327 | 387 | 333 | 392 | 336 | 401 | 341½ |
| $FF^\#$ | 390 | 335 | 395 | 342 | 400 | 346 | 411 | 351 |
| FF | 397 | 343 | 403 | 350 | 408 | 355 | 421 | 363 |

**Table A1.2b**
**Number of string pairs per Zoll for the FF to $f^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $f^3$ | 12 in 2¼ | | 12 in 2¼ | | 12 in 2¼ | | 12 in 2¼ | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | | | | | | |
| $c^3$ | | | | | | | | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | 12 in 2¼ | | 12 in 2¼ | | 12 in 2¼ | | 12 in 2¼ | |
| $f^2$ | 12 in 2½ | | 12 in 2½ | | 12 in 2½ | | 12 in 2½ | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | | | | |
| $c^2$ | | | | | | | | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | 12 in 2½ | | 12 in 2½ | | 12 in 2½ | | 12 in 2½ | |
| $f^1$ | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | | | | | | | | |
| $c^1$ | | | | | | | | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| g# | | | | | | | | |
| g | | | | | | | | |
| f# | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | | 12 in $3^1/_3$ | |
| f | 24 in 7 | | 24 in 7¼ | | 24 in 7¼ | | 24 in 8 | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| 1d | | 9 in 2¼ | | 9 in 2½ | | | | |
| c# | | | | | | | | |
| c | | | | | | | | 7 in 2 |
| B | | | | | | 6 in 1½ | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| G# | | | | | | | | |
| G | | | | | | | | |
| F# | | 9 in 2¼ | | 9 in 2½ | | 6 in 1½ | | 7 in 2 |
| F | | 12 in 4 | | 12 in 4 | | 12 in 4 | | 12 in 4½ |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| C# | | | | | | | | |
| C | | | | | | | | |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| GG# | | | | | | | | |
| GG | | | | | | | | |
| FF# | | | | | | | | |
| FF | 24 in 7 | 12 in 4 | 24 in 7¼ | 12 in 4 | 24 in 7¼ | 12 in 4 | 24 in 8 | 12 in 4½ |

## Table A1.2c
## Marking-out stick divisions for the FF to $f^3$ models

### Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft | 8ft | 4ft |
| $f^3$ | 16 in 3 | | 16 in 3 | | 16 in 3 | | 16 in 3 | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | | | | | | |
| $c^3$ | | | | | | | | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | 16 in 3 | | 16 in 3 | | 16 in 3 | | 16 in 3 | |
| $f^2$ | 24 in 5 | | 24 in 5 | | 24 in 5 | | 24 in 5 | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | | | | |
| $c^2$ | | | | | | | | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | 24 in 5 | | 24 in 5 | | 24 in 5 | | 24 in 5 | |
| $f^1$ | 18 in 5 | | 18 in 5 | | 18 in 5 | | 18 in 5 | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | | | | | | | | |
| $c^1$ | | | | | | | | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| $g^\#$ | | | | | | | | |
| g | | | | | | | | |
| $f^\#$ | 18 in 5 | | 18 in 5 | | 18 in 5 | | 18 in 5 | |
| f | 24 in 7 | | ≈10 in 3 | | ≈10 in 3 | | 3 in 1 | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| d | | 4 in 1 | | 18 in 5 | | | | |
| $c^\#$ | | | | | | | | |
| c | | | | | | | | 7 in 2 |
| B | | | | | | 4 in 1 | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| $G^\#$ | | | | | | | | |
| G | | | | | | | | |
| $F^\#$ | | 4 in 1 | | 18 in 5 | | 4 in 1 | | 7 in 2 |
| F | | 3 in 1 | | 3 in 1 | | 3 in 1 | | 8 in 3 |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| $C^\#$ | | | | | | | | |
| C | | | | | | | | |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| $GG^\#$ | | | | | | | | |
| GG | | | | | | | | |
| $FF^\#$ | | | | | | | | |
| FF | 24 in 7 | 3 in 1 | ≈10 in 3 | 3 in 1 | ≈10 in 3 | 3 in 1 | 3 in 1 | 8 in 3 |

**Table A1.3a**
**Distance of the 8ft and 4ft bridge pins from the spine of two unique models**

| | 1732b HH FF to $d^3$ | | 1748 JH GG to $d^3$ | | |
|---|---|---|---|---|---|
| | 8ft | 4ft | 8ft | 4ft | |
| $d^3$ | 35 | | 44½ | | $d^3$ |
| $c\#^3$ | 39 | | 48½ | | $c\#^3$ |
| $c^3$ | 43 | | 53 | | $c^3$ |
| $b^2$ | 47 | | 57½ | | $b^2$ |
| $b^{b2}$ | 52 | | 62 | | $b^{b2}$ |
| $a^2$ | 56½ | | 66½ | | $a^2$ |
| $g\#^2$ | 62 | | 71 | | $g\#^2$ |
| $g^2$ | 67 | | 76 | | $g^2$ |
| $f\#^2$ | 72 | | 80½ | | $f\#^2$ |
| $f^2$ | 76 | | 85 | | $f^2$ |
| $e^2$ | 81 | | 90 | | $e^2$ |
| $e^{b2}$ | 86 | | 94 | | $e^{b2}$ |
| $d^2$ | 90 | | 98 | | $d^2$ |
| $c\#^2$ | 94½ | | 102½ | | $c\#^2$ |
| $c^2$ | 99½ | | 108 | | $c^2$ |
| $b^1$ | 105 | | 112½ | | $b^1$ |
| $b^{b1}$ | 111½ | | 118 | | $b^{b1}$ |
| $a^1$ | 115 | | 123 | | $a^1$ |
| $g\#^1$ | 120 | | 128½ | | $g\#^1$ |
| $g^1$ | 126 | | 133½ | | $g^1$ |
| $f\#^1$ | 131½ | | 138½ | | $f\#^1$ |
| $f^1$ | 137 | | 144 | | $f^1$ |
| $e^1$ | 142½ | | 149 | | $e^1$ |
| $e^{b1}$ | 148 | | 155 | | $e^{b1}$ |
| $d^1$ | 153½ | | 161 | | $d^1$ |
| $c\#^1$ | 160 | | 166 | | $c\#^1$ |
| $c^1$ | 167 | | 171½ | | $c^1$ |
| b | 173½ | | 178 | | b |
| $b^b$ | 180 | | 185 | | $b^b$ |
| a | 187 | | 193 | | a |
| g# | 193½ | | 200 | | g# |
| g | 200 | | 208 | | g |
| f# | 207 | | 217 | | f# |
| f | 214 | | 225 | | f |
| e | 221 | | 233 | | e |
| $e^b$ | 228 | | 242 | | $e^b$ |
| d | 234 | 181 | 250 | 201 | d |
| c# | 241½ | 187 | 258 | 207 | c# |
| c | 246½ | 192 | 265 | 214 | c |
| B | 253 | 198 | 272 | 220 | B |
| $B^b$ | 261 | 202 | 280 | 227 | $B^b$ |
| A | 268 | 210 | 287 | 234 | A |
| G# | 274 | 216 | 295 | 241 | G# |
| G | 281½ | 222½ | 302½ | 248 | G |
| F# | 289 | 229½ | 310 | 256 | F# |
| F | 296 | 236 | 317 | 263 | F |
| E | 303 | 243½ | 325 | 271 | E |
| $E^b$ | 310 | 251 | 333 | 278 | $E^b$ |
| D | 317½ | 259 | 340 | 286 | D |
| C# | 325 | 266 | 347½ | 294 | C# |
| C | 332½ | 274 | 355 | 302 | C |
| BB | 340 | 282 | 363 | 311 | BB |
| $BB^b$ | 347 | 289½ | 370½ | 319 | $BB^b$ |
| AA | 355 | 297 | 378 | 328 | AA |
| GG# | 362 | 304½ | 386 | 336½ | GG# |
| GG | 369 | 314 | 394½ | 345 | GG |
| FF# | 377 | 321 | | | FF# |
| FF | 383 | 330 | | | FF |

**Table A1.3b**
**Number of string pairs per Zoll for two unique models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1732b HH FF to $d^3$ 8ft | 1732b HH FF to $d^3$ 4ft | 1748 JH GG to $d^3$ 8ft | 1748 JH GG to $d^3$ 4ft | |
|---|---|---|---|---|---|
| $d^3$ | 9 in 1 11/16 | | 7 in 1 5/16 | | $d^3$ |
| $c^{\#3}$ | | | | | $c^{\#3}$ |
| $c^3$ | | | | | $c^3$ |
| $b^2$ | | | | | $b^2$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^2$ | | | | | $a^2$ |
| $g^{\#2}$ | | | 7 in 1 5/16 | | $g^{\#2}$ |
| $g^2$ | | | 12 in 2½ | | $g^2$ |
| $f^{\#2}$ | 9 in 1 11/16 | | | | $f^{\#2}$ |
| $f^2$ | 12 in 2½ | | | | $f^2$ |
| $e^2$ | | | | | $e^2$ |
| $e^{b2}$ | | | | | $e^{b2}$ |
| $d^2$ | | | | | $d^2$ |
| $c^{\#2}$ | | | | | $c^{\#2}$ |
| $c^2$ | | | | | $c^2$ |
| $b^1$ | | | | | $b^1$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^1$ | | | | | $a^1$ |
| $g^{\#1}$ | | | 12 in 2½ | | $g^{\#1}$ |
| $g^1$ | | | 12 in 3 | | $g^1$ |
| $f^{\#1}$ | 12 in 2½ | | | | $f^{\#1}$ |
| $f^1$ | 12 in 3 1/3 | | | | $f^1$ |
| $e^1$ | | | | | $e^1$ |
| $e^{b1}$ | | | | | $e^{b1}$ |
| $d^1$ | | | | | $d^1$ |
| $c^{\#1}$ | | | | | $c^{\#1}$ |
| $c^1$ | | | | | $c^1$ |
| b | | | | | b |
| $b^b$ | | | | | $b^b$ |
| a | | | | | a |
| $g^\#$ | | | 12 in 3 | | $g^\#$ |
| g | | | 24 in 7¼ | | g |
| $f^\#$ | 12 in 3 1/3 | | | | $f^\#$ |
| f | 24 in 7 | | | | f |
| e | | | | | e |
| $e^b$ | | | | | $e^b$ |
| d | | 9 in 2¼ | | 7 in 2 | d |
| $c^\#$ | | | | | $c^\#$ |
| c | | | | | c |
| B | | | | | B |
| $B^b$ | | | | | $B^b$ |
| A | | | | | A |
| $G^\#$ | | | | 7 in 2 | $G^\#$ |
| G | | | | 12 in 4 | G |
| $F^\#$ | | 9 in 2¼ | | | $F^\#$ |
| F | | 12 in 4 | | | F |
| E | | | | | E |
| $E^b$ | | | | | $E^b$ |
| D | | | | | D |
| $C^\#$ | | | | | $C^\#$ |
| C | | | | | C |
| BB | | | | | BB |
| $BB^b$ | | | | | $BB^b$ |
| AA | | | | | AA |
| $GG^\#$ | | | | | $GG^\#$ |
| GG | | | 24 in 7¼ | 12 in 4 | GG |
| $FF^\#$ | | | | | |
| FF | 24 in 7 | 12 in 4 | | | |

**Table A1.3c**
**Marking-out stick divisions for two unique models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 1732b HH FF to $d^3$ 8ft | 1732b HH FF to $d^3$ 4ft | 1748 JH GG to $d^3$ 8ft | 1748 JH GG to $d^3$ 4ft | |
|---|---|---|---|---|---|
| $d^3$ | 16 in 3 | | 16 in 3 | | $d^3$ |
| $c^{\#3}$ | | | | | $c^{\#3}$ |
| $c^3$ | | | | | $c^3$ |
| $b^2$ | | | | | $b^2$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^2$ | | | | | $a^2$ |
| $g^{\#2}$ | | | 16 in 3 | | $g^{\#2}$ |
| $g^2$ | | | 24 in 5 | | $g^2$ |
| $f^{\#2}$ | 16 in 3 | | | | $f^{\#2}$ |
| $f^2$ | 24 in 5 | | | | $f^2$ |
| $e^2$ | | | | | $e^2$ |
| $e^{b2}$ | | | | | $e^{b2}$ |
| $d^2$ | | | | | $d^2$ |
| $c^{\#2}$ | | | | | $c^{\#2}$ |
| $c^2$ | | | | | $c^2$ |
| $b^1$ | | | | | $b^1$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^1$ | | | | | $a^1$ |
| $g^{\#1}$ | | | 24 in 5 | | $g^{\#1}$ |
| $g^1$ | | | 4 in 1 | | $g^1$ |
| $f^{\#1}$ | 24 in 5 | | | | $f^{\#1}$ |
| $f^1$ | 18 in 5 | | | | $f^1$ |
| $e^1$ | | | | | $e^1$ |
| $e^{b1}$ | | | | | $e^{b1}$ |
| $d^1$ | | | | | $d^1$ |
| $c^{\#1}$ | | | | | $c^{\#1}$ |
| $c^1$ | | | | | $c^1$ |
| b | | | | | b |
| $b^b$ | | | | | $b^b$ |
| a | | | | | a |
| $g^\#$ | | | 4 in 1 | | $g^\#$ |
| g | | | ≈10 in 3 | | g |
| $f^\#$ | 18 in 5 | | | | $f^\#$ |
| f | 24 in 7 | | | | f |
| e | | | | | e |
| $e^b$ | | | | | $e^b$ |
| d | | 4 in 1 | | 7 in 2 | d |
| $c^\#$ | | | | | $c^\#$ |
| c | | | | | c |
| B | | | | | B |
| $B^b$ | | | | | $B^b$ |
| A | | | | | A |
| $G^\#$ | | | | 7 in 2 | $G^\#$ |
| G | | | | 3 in 1 | G |
| $F^\#$ | | 4 in 1 | | | $F^\#$ |
| F | | 3 in 1 | | | F |
| E | | | | | E |
| $E^b$ | | | | | $E^b$ |
| D | | | | | D |
| $C^\#$ | | | | | $C^\#$ |
| C | | | | | C |
| BB | | | | | BB |
| $BB^b$ | | | | | $BB^b$ |
| AA | | | | | AA |
| $GG^\#$ | | | | | $GG^\#$ |
| GG | | | ≈10 in 3 | 3 in 1 | GG |
| $FF^\#$ | | | | | |
| FF | 24 in 7 | 3 in 1 | | | |

# Appendix 2:

## DETERMINATION OF THE MARKING OUT OF THE POSITION OF THE 8FT TUNING PINS AND THE 4FT HITCHPINS

**Table A2.1a**
**Distance of the 8ft tuning pins and the 4ft hitchpins from the spine of the C to $d^3$ models**

**(1725) HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| | --- | |
| $c^{\#3}$-$d^3$ | 38 | |
| $b^2$-$c^3$ | 43½ | |
| $a^2$-$b^{b2}$ | 50 | |
| $g^2$-$g^{\#2}$ | 55 | |
| $f^2$-$f^{\#2}$ | 62 | |
| $e^{b2}$-$e^2$ | 67 | |
| $d^2$ | 72 | |
| $c^2$-$c^{\#2}$ | 77 | |
| $b^{b1}$-$b^1$ | 83 | |
| $a^1$ | 90 | |
| $g^1$-$g^{\#1}$ | 98 | |
| $f^1$-$f^{\#1}$ | 104 | |
| $e^{b1}$-$e^1$ | 111 | |
| $d^1$ | 119 | |
| $c^1$-$c^{\#1}$ | 126 | |
| $b^b$-b | 134 | |
| a | 143 | |
| g-$g^\#$ | 151 | |
| f-$f^\#$ | 159½ | |
| $e^b$-e | 169 | |
| d | 178 | 136 |
| $c^\#$ | 187½ | 143 |
| c | 197 | 151 |
| B | 206 | 159½ |
| $B^b$ | 215 | 167 |
| A | 223½ | 176 |
| $G^\#$ | 233 | 185 |
| G | 242 | 195 |
| $F^\#$ | 252 | 204 |
| F | 261 | 213 |
| E | 270 | 223 |
| $E^b$ | 280 | 233 |
| D | 290 | 242 |
| $C^\#$ | 297 | 252½ |
| C | 307 | 262 |

**1740b HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 35 | |
| $c^3$-$c^{\#3}$ | 41 | |
| $b^{b2}$-$b^2$ | 46 | |
| $a^2$ | 52 | |
| $g^2$-$g^{\#2}$ | 58 | |
| $f^2$-$f^{\#2}$ | 63 | |
| $e^{b2}$-$e^2$ | 69 | |
| $d^2$ | 75 | |
| $c^2$-$c^{\#2}$ | 81 | |
| $b^{b1}$-$b^1$ | 88 | |
| $a^1$ | 94 | |
| $g^1$-$g^{\#1}$ | 101 | |
| $f^1$-$f^{\#1}$ | 109 | |
| $e^{b1}$-$e^1$ | 115 | |
| $d^1$ | 122 | |
| $c^1$-$c^{\#1}$ | 130 | |
| $b^b$-b | 139 | |
| a | 148 | |
| g-$g^\#$ | 157 | |
| f-$f^\#$ | 167 | |
| $e^b$-e | 175 | |
| d | 184 | 138 |
| $c^\#$ | 193 | 145 |
| c | 204 | 154 |
| B | 211 | 162 |
| $B^b$ | 221 | 171 |
| A | 230 | 177½ |
| $G^\#$ | 240 | 188 |
| G | 248 | 197 |
| $F^\#$ | 259 | 207 |
| F | 268 | 215 |
| E | 277 | 224 |
| $E^b$ | 286 | 233 |
| D | 296 | 242 |
| $C^\#$ | 304 | 251 |
| C | 313 | 262 |

**1761b JH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 32 | |
| $c^3$-$c^{\#3}$ | 38 | |
| $b^{b2}$-$b^2$ | 44 | |
| $a^2$ | 51 | |
| $g^2$-$g^{\#2}$ | 58 | |
| $f^2$-$f^{\#2}$ | 64 | |
| $e^{b2}$-$e^2$ | 70 | |
| $d^2$ | 76 | |
| $c^2$-$c^{\#2}$ | 83 | |
| $b^{b1}$-$b^1$ | 89 | |
| $a^1$ | 96½ | |
| $g^1$-$g^{\#1}$ | 104 | |
| $f^1$-$f^{\#1}$ | 110 | |
| $e^{b1}$-$e^1$ | 117 | |
| $d^1$ | 124½ | |
| $c^1$-$c^{\#1}$ | 131 | |
| $b^b$-b | 140 | |
| a | 149 | |
| g-$g^\#$ | 158 | |
| f-$f^\#$ | 168 | |
| e | 178 | |
| $e^b$ | 186½ | |
| d | 195 | 150 |
| $c^\#$ | 204 | 158 |
| c | 215 | 166 |
| B | 223 | 174 |
| $B^b$ | 233 | 181 |
| A | 243 | 189 |
| $G^\#$ | 252 | 197 |
| G | 261 | 206 |
| $F^\#$ | 271 | 216½ |
| F | 280 | 225 |
| E | 289 | 234½ |
| $E^b$ | 298 | 245 |
| D | 308 | 255 |
| $C^\#$ | 317½ | 266 |
| C | 326 | 275 |

**Table A2.1b**
**Number of string pairs per Zoll for the C to $d^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

**(1725) HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $c^{\#3}-d^3$ | 7 in $1\frac{1}{2}$ | |
| $b^2-c^3$ | | |
| $a^2-b^{b2}$ | | |
| $g^2-g^{\#2}$ | | |
| $f^2-f^{\#2}$ | | |
| $e^{b2}-e^2$ | | |
| $d^2$ | 7 in $1\frac{1}{2}$ | |
| $c^2-c^{\#2}$ | 7 in 2 | |
| $b^{b1}-b^1$ | | |
| $a^1$ | | |
| $g^1-g^{\#1}$ | | |
| $f^1-f^{\#1}$ | | |
| $e^{b1}-e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1-c^{\#1}$ | 20 in $7\frac{1}{2}$ | |
| $b^b-b$ | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b-e$ | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 20 in $7\frac{1}{2}$ | 5 in 2 |

**1740b HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 8 in 2 | |
| $c^3-c^{\#3}$ | | |
| $b^{b2}-b^2$ | | |
| $a^2$ | | |
| $g^2-g^{\#2}$ | | |
| $f^2-f^{\#2}$ | | |
| $e^{b2}-e^2$ | | |
| $d^2$ | 8 in 2 | |
| $c^2-c^{\#2}$ | 7 in 2 | |
| $b^{b1}-b^1$ | | |
| $a^1$ | | |
| $g^1-g^{\#1}$ | | |
| $f^1-f^{\#1}$ | | |
| $e^{b1}-e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1-c^{\#1}$ | 20 in $7\frac{1}{2}$ | |
| $b^b-b$ | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b-e$ | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 20 in $7\frac{1}{2}$ | 5 in 2 |

**1761b JH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 8 in 2 | |
| $c^3-c^{\#3}$ | | |
| $b^{b2}-b^2$ | | |
| $a^2$ | | |
| $g^2-g^{\#2}$ | | |
| $f^2-f^{\#2}$ | | |
| $e^{b2}-e^2$ | | |
| $d^2$ | 8 in 2 | |
| $c^2-c^{\#2}$ | 7 in 2 | |
| $b^{b1}-b^1$ | | |
| $a^1$ | | |
| $g^1-g^{\#1}$ | | |
| $f^1-f^{\#1}$ | | |
| $e^{b1}-e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1-c^{\#1}$ | 21 in $8^1/_6$ | |
| $b^b-b$ | | |
| a | | |
| g-g# | | |
| f-f# | | |
| e | | |
| $e^b$ | | |
| d | | 9 in 3 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 9 in 3 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 21 in $8^1/_6$ | 5 in 2 |

**Table A2.1c**
**Marking-out stick divisions for the C to d$^3$ models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

**(1725) HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $c^{\#3}$-$d^3$ | 14 in 3 | |
| $b^2$-$c^3$ | | |
| $a^2$-$b^{b2}$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 14 in 3 | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b1}$-$e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 8 in 3 | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b$-e | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 8 in 3 | 5 in 2 |

**1740b HH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 4 in 1 | |
| $c^3$-$c^{\#3}$ | | |
| $b^{b2}$-$b^2$ | | |
| $a^2$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 4 in 1 | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b1}$-$e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 8 in 3 | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| $e^b$-e | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 8 in 3 | 5 in 2 |

**1761b JH**

| | 8ft TUNING PINS | 4ft HITCH PINS |
|---|---|---|
| $d^3$ | 4 in 1 | |
| $c^3$-$c^{\#3}$ | | |
| $b^{b2}$-$b^2$ | | |
| $a^2$ | | |
| $g^2$-$g^{\#2}$ | | |
| $f^2$-$f^{\#2}$ | | |
| $e^{b2}$-$e^2$ | | |
| $d^2$ | 4 in 1 | |
| $c^2$-$c^{\#2}$ | 7 in 2 | |
| $b^{b1}$-$b^1$ | | |
| $a^1$ | | |
| $g^1$-$g^{\#1}$ | | |
| $f^1$-$f^{\#1}$ | | |
| $e^{b1}$-$e^1$ | | |
| $d^1$ | 7 in 2 | |
| $c^1$-$c^{\#1}$ | 18 in 7 | |
| $b^b$-b | | |
| a | | |
| g-g# | | |
| f-f# | | |
| e | | |
| $e^b$ | | |
| d | | 3 in 1 |
| c# | | |
| c | | |
| B | | |
| $B^b$ | | |
| A | | |
| G# | | |
| G | | |
| F# | | 3 in 1 |
| F | | 5 in 2 |
| E | | |
| $E^b$ | | |
| D | | |
| C# | | |
| C | 18 in 7 | 5 in 2 |

**Table A2.2a**
**Distance of the 8ft tuning pins and the 4ft hitchpins from the spine of the FF to $f^3$ models**

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS |
| $f^3$ | | | | | | | | |
| $e^3$ | 36 | | 35 | | 35 | | 39 | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | 46½ | | 46 | | 44 | | 50 | |
| $c^{\#3}$ | | | | | | | | |
| $c^3$ | 56½ | | 56½ | | 54½ | | 59½ | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | 66 | | 66 | | 65 | | 70 | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | 77 | | 76 | | 76 | | 80 | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | 88 | | 87 | | 86½ | | 93 | |
| $f^2$ | | | | | | | | |
| $e^2$ | 99 | | 97 | | 96 | | 101 | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | 110 | | 108½ | | 108 | | 111 | |
| $c^{\#2}$ | | | | | | | | |
| $c^2$ | 121 | | 119 | | 119 | | 122 | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | 133 | | 129 | | 130½ | | 133 | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | 146 | | 139 | | 140 | | 143 | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | 158 | | 149 | | 152 | | 154 | |
| $f^1$ | | | | | | | | |
| $e^1$ | 171 | | 159 | | 162 | | 166 | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | 184 | | 171 | | 175 | | 179½ | |
| $c^{\#1}$ | | | | | | | | |
| $c^1$ | 196 | | 183 | | 188 | | 191 | |
| b | | | | | | | | |
| $b^b$ | 209 | | 195 | | 201 | | 205 | |
| a | | | | | | | | |
| $g^\#$ | 223 | | 207 | | 216 | | 219 | |
| g | | | | | | | | |
| $f^\#$ | 235 | | 221 | | 229 | | 233 | |
| f | | | | | | | | |
| e | 248 | | 235 | | 241½ | | 247 | |
| $e^b$ | | | | | | | | |
| d | 260½ | 202 | 251 | 199 | 254 | | 261 | |
| $c^\#$ | 268 | 207 | | 206 | | | | |
| c | 274 | 212 | 266 | 213 | 270 | | 275 | 209½ |
| B | 282 | 216½ | | 219 | | 219 | | 216 |
| $B^b$ | 288 | 221½ | 285 | 226 | 284 | 225 | 286½ | 223 |
| A | 294½ | 227 | 292½ | 231 | 292½ | 232 | 296 | 229½ |
| $G^\#$ | 302 | 234 | 301 | 237 | 300 | 239½ | 304 | 236 |
| G | 309 | 240 | 308 | 245 | 307 | 246 | 314 | 243 |
| $F^\#$ | 316 | 247 | 316 | 251 | 316 | 254 | 321 | 251 |
| F | 323 | 256 | 322 | 258 | 324 | 261 | 328½ | 259 |
| E | 337 | 263 | 330½ | 266 | 332 | 269 | 336 | 268 |
| $E^b$ | 345 | 270 | 338½ | 274 | 340 | 277 | 345 | 275 |
| D | 352 | 278 | 347 | 282 | 349 | 284 | 352½ | 283 |
| $C^\#$ | 359½ | 286 | 353 | 290 | 356½ | 292 | 360 | 291 |
| C | 366 | 293 | 361 | 299 | 364 | 302 | 367½ | 299 |
| BB | 375 | 301 | 369½ | 307 | 396 | 310 | 402 | 308 |
| $BB^b$ | 381 | 308 | 376 | 315 | 403 | 318 | 407 | 317 |
| AA | 389 | 317 | 383 | 322½ | 411½ | 326 | 419 | 325½ |
| $GG^\#$ | 395 | 325 | 390 | 332 | 418½ | 355 | 423 | 336 |
| GG | 403½ | 333 | 397 | 342 | 428 | 343 | 433 | 346½ |
| $FF^\#$ | 409 | 342 | 406 | 353 | 439 | 353 | 441½ | 356 |
| FF | 417½ | 351 | 414 | 364 | 447 | 360½ | 449½ | 367 |

**Table A2.2b**
**Number of string pairs per Zoll for the FF to $f^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS |
| $f^3$ | 19 in 9½ | | 21 in 10½ | | 21 in 10½ | | 21 in 10½ | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | | | | | | |
| $c^3$ | | | | | | | | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | | | | | | | | |
| $f^2$ | | | | | | | | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | | | | |
| $c^2$ | | | | | | | | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | | | | | | | | |
| $f^1$ | | | | | | | | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | | | | | | | | |
| $c^1$ | | | | | | | | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| $g^\#$ | | | | | | | | |
| g | | | | | | | | |
| $f^\#$ | | | | | | | | |
| f | | | | | | | | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| d | 19 in 9½ | 9 in 2¼ | | 9 in 2½ | | | | |
| $c^\#$ | 8 in 2²/₇ | | | | | | | |
| c | | | | | | | | 7 in 2 |
| B | | | | | | 6 in 1²/₃ | | |
| $B^b$ | | | 21 in 10½ | | 21 in 10½ | | 21 in 10½ | |
| A | | | 16 in 5 | | 9 in 3 | | 9 in 3 | |
| $G^\#$ | | | | | | | | |
| G | | | | | | | | |
| $F^\#$ | | 9 in 2¼ | | 9 in 2½ | | 6 in 1²/₃ | | 7 in 2 |
| F | 8 in 2²/₇ | 12 in 4 | | 12 in 4½ | | 12 in 4 | | 12 in 4½ |
| E | 11 in 3⁵/₂₄ | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| $C^\#$ | | | | | | | | |
| C | | | | | 9 in 3 | | 9 in 3 | |
| BB | | | | | 6 in 2 | | 6 in 2 | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| $GG^\#$ | | | | | | | | |
| GG | | | | | | | | |
| $FF^\#$ | | | | | | | | |
| FF | 11 in 3⁵/₂₄ | 12 in 4 | 16 in 5 | 12 in 4½ | 6 in 2 | 12 in 4 | 6 in 2 | 12 in 4½ |

**Table A2.2c**
**Marking-out stick divisions for the FF to f³ models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 1742a HH | | 1744a HH | | 1763a JH | | 1767 JH | |
|---|---|---|---|---|---|---|---|---|
| | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS |
| $f^3$ | 2 in 1 | | 2 in 1 | | 2 in 1 | | 2 in 1 | |
| $e^3$ | | | | | | | | |
| $e^{b3}$ | | | | | | | | |
| $d^3$ | | | | | | | | |
| $c^{\#3}$ | | | | | | | | |
| $c^3$ | | | | | | | | |
| $b^2$ | | | | | | | | |
| $b^{b2}$ | | | | | | | | |
| $a^2$ | | | | | | | | |
| $g^{\#2}$ | | | | | | | | |
| $g^2$ | | | | | | | | |
| $f^{\#2}$ | | | | | | | | |
| $f^2$ | | | | | | | | |
| $e^2$ | | | | | | | | |
| $e^{b2}$ | | | | | | | | |
| $d^2$ | | | | | | | | |
| $c^{\#2}$ | | | | | | | | |
| $c^2$ | | | | | | | | |
| $b^1$ | | | | | | | | |
| $b^{b1}$ | | | | | | | | |
| $a^1$ | | | | | | | | |
| $g^{\#1}$ | | | | | | | | |
| $g^1$ | | | | | | | | |
| $f^{\#1}$ | | | | | | | | |
| $f^1$ | | | | | | | | |
| $e^1$ | | | | | | | | |
| $e^{b1}$ | | | | | | | | |
| $d^1$ | | | | | | | | |
| $c^{\#1}$ | | | | | | | | |
| $c^1$ | | | | | | | | |
| b | | | | | | | | |
| $b^b$ | | | | | | | | |
| a | | | | | | | | |
| $g^\#$ | | | | | | | | |
| g | | | | | | | | |
| $f^\#$ | | | | | | | | |
| f | | | | | | | | |
| e | | | | | | | | |
| $e^b$ | | | | | | | | |
| d | 2 in 1 | 4 in 1 | | 18 in 5 | | | | |
| $c^\#$ | 7 in 2 | | | | | | | |
| c | | | | | | | | 7 in 2 |
| B | | | | | | 18 in 5 | | |
| $B^b$ | | | 2 in 1 | | 2 in 1 | | 2 in 1 | |
| A | | | 16 in 5 | | 3 in 1 | | 3 in 1 | |
| $G^\#$ | | | | | | | | |
| G | | | | | | | | |
| $F^\#$ | | 4 in 1 | | 18 in 5 | | 18 in 5 | | 7 in 2 |
| F | 7 in 2 | 3 in 1 | | 8 in 3 | | 3 in 1 | | 8 in 3 |
| E | 24 in 7 | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| $C^\#$ | | | | | | | | |
| C | | | | | 3 in 1 | | 3 in 1 | |
| BB | | | | | 3 in 1 | | 3 in 1 | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| $GG^\#$ | | | | | | | | |
| GG | | | | | | | | |
| $FF^\#$ | | | | | | | | |
| FF | 24 in 7 | 3 in 1 | 16 in 5 | 8 in 3 | 3 in 1 | 3 in 1 | 3 in 1 | 8 in 3 |

**Table A2.3a**
**Distance of the 8ft tuning pins and the 4ft hitchpins from the spine for two unique models**

| | 1732b HH | | 1748 JH | | |
|---|---|---|---|---|---|
| | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | |
| $d^3$ | | | | | $d^3$ |
| $c^{\#3}$ | 32 | | 45½ | | $c^{\#3}$ |
| $c^3$ | | | | | $c^3$ |
| $b^2$ | 42 | | 56 | | $b^2$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^2$ | 52 | | 67½ | | $a^2$ |
| $g^{\#2}$ | | | | | $g^{\#2}$ |
| $g^2$ | 63 | | 78 | | $g^2$ |
| $f^{\#2}$ | | | | | $f^{\#2}$ |
| $f^2$ | 74 | | 89 | | $f^2$ |
| $e^2$ | | | | | $e^2$ |
| $e^b$ | 84 | | 100 | | $e^{b2}$ |
| $d^2$ | | | | | $d^2$ |
| $c^{\#2}$ | 94 | | 110 | | $c^{\#2}$ |
| $c^2$ | | | | | $c^2$ |
| $b^1$ | 104 | | 121½ | | $b^1$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^1$ | 115 | | 132 | | $a^1$ |
| $g^{\#1}$ | | | | | $g^{\#1}$ |
| $g^1$ | 126 | | 142 | | $g^1$ |
| $f^{\#1}$ | | | | | $f^{\#1}$ |
| $f^1$ | 138 | | 153 | | $f^1$ |
| $e^1$ | | | | | $e^1$ |
| $e^{b1}$ | 149 | | 164½ | | $e^{b1}$ |
| $d^1$ | | | | | $d^1$ |
| $c^{\#1}$ | 161 | | 175 | | $c^{\#1}$ |
| $c^1$ | | | | | $c^1$ |
| b | 174½ | | 188 | | b |
| $b^b$ | | | | | $b^b$ |
| a | 188 | | 202 | | a |
| g# | | | | | g# |
| g | 201 | | 217 | | g |
| f# | | | | | f# |
| f | 215 | | 232½ | | f |
| e | | | | | e |
| $e^b$ | 230 | | 249 | | $e^b$ |
| d | 243 | 183 | | 205 | d |
| c# | 250½ | 189½ | 266 | 212 | c# |
| c | 260 | 196 | 275½ | 219 | c |
| B | 266 | 202½ | 284 | 226 | B |
| $B^b$ | 274 | 208 | 291 | 232 | $B^b$ |
| A | 281 | 216 | 300 | 239 | A |
| G# | 289 | 221½ | 308 | 247 | G# |
| G | 296 | 228 | 313 | 255 | G |
| F# | 303 | 234 | 320½ | 262 | F# |
| F | 310 | 240½ | 329 | 270 | F |
| E | 318 | 247 | 341 | 277 | E |
| $E^b$ | 324 | 255 | 348 | 286 | $E^b$ |
| D | 332 | 263½ | 356 | 294 | D |
| C# | 338 | 271 | 363 | 302 | C# |
| C | 345½ | 280 | 370 | 310½ | C |
| BB | 352 | 288 | 377 | 319 | BB |
| $BB^b$ | 360 | 296½ | 386 | 327½ | $BB^b$ |
| AA | 369 | 304½ | 392 | 335½ | AA |
| GG# | 377 | 313 | 400 | 344 | GG# |
| GG | 385 | 322 | 411 | 353 | GG |
| FF# | 393 | 332 | | | |
| FF | 403 | 341 | | | |

**Table A2.3b**
**Number of string pairs per Zoll for two unique models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1732b HH 8ft TUNING PINS | 1732b HH 4ft HITCH PINS | 1748 JH 8ft TUNING PINS | 1748 JH 4ft HITCH PINS | |
|---|---|---|---|---|---|
| $d^3$ | 17 in 8½ | | 18 in 9 | | $d^3$ |
| $c^{\#3}$ | | | | | $c^{\#3}$ |
| $c^3$ | | | | | $c^3$ |
| $b^2$ | | | | | $b^2$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^2$ | | | | | $a^2$ |
| $g^{\#2}$ | | | | | $g^{\#2}$ |
| $g^2$ | | | | | $g^2$ |
| $f^{\#2}$ | | | | | $f^{\#2}$ |
| $f^2$ | | | | | $f^2$ |
| $e^2$ | | | | | $e^2$ |
| $e^b$ | | | | | $e^{b2}$ |
| $d^2$ | | | | | $d^2$ |
| $c^{\#2}$ | | | | | $c^{\#2}$ |
| $c^2$ | | | | | $c^2$ |
| $b^1$ | | | | | $b^1$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^1$ | | | | | $a^1$ |
| $g^{\#1}$ | | | | | $g^{\#1}$ |
| $g^1$ | | | | | $g^1$ |
| $f^{\#1}$ | | | | | $f^{\#1}$ |
| $f^1$ | | | | | $f^1$ |
| $e^1$ | | | | | $e^1$ |
| $e^{b1}$ | | | | | $e^{b1}$ |
| $d^1$ | | | | | $d^1$ |
| $c^{\#1}$ | | | | | $c^{\#1}$ |
| $c^1$ | | | | | $c^1$ |
| b | | | | | b |
| $b^b$ | | | | | $b^b$ |
| a | | | | | a |
| g# | | | | | g# |
| g | | | | | g |
| f# | | | | | f# |
| f | | | | | f |
| e | | | | | e |
| $e^b$ | 17 in 8½ | | | | $e^b$ |
| d | 21 in $6^9/_{16}$ | 9 in 2½ | 18 in 9 | 7 in 2 | d |
| c# | | | 18 in 6 | | c# |
| c | | | | | c |
| B | | | | | B |
| $B^b$ | | | | | $B^b$ |
| A | | | | | A |
| G# | | | | 7 in 2 | G# |
| G | | | | 12 in 4 | G |
| F# | | 9 in 2½ | | | F# |
| F | | 12 in 4 | | | F |
| E | | | | | E |
| $E^b$ | | | | | $E^b$ |
| D | | | | | D |
| C# | | | | | C# |
| C | | | | | C |
| BB | | | | | BB |
| $BB^b$ | | | | | $BB^b$ |
| AA | | | | | AA |
| GG# | | | | | GG# |
| GG | | | 18 in 6 | 12 in 4 | GG |
| FF# | | | | | |
| FF | 21 in $6^9/_{16}$ | 12 in 4 | | | |

**Table A2.3c**
**Marking-out stick divisions for two unique models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 1732b HH | | 1748 JH | | |
|---|---|---|---|---|---|
| | 8ft TUNING PINS | 4ft HITCH PINS | 8ft TUNING PINS | 4ft HITCH PINS | |
| $d^{3}$ | 2 in 1 | | 2 in 1 | | $d^{3}$ |
| $c^{\#3}$ | | | | | $c^{\#3}$ |
| $c^{3}$ | | | | | $c^{3}$ |
| $b^{2}$ | | | | | $b^{2}$ |
| $b^{b2}$ | | | | | $b^{b2}$ |
| $a^{2}$ | | | | | $a^{2}$ |
| $g^{\#2}$ | | | | | $g^{\#2}$ |
| $g^{2}$ | | | | | $g^{2}$ |
| $f^{\#2}$ | | | | | $f^{\#2}$ |
| $f^{2}$ | | | | | $f^{2}$ |
| $e^{2}$ | | | | | $e^{2}$ |
| $e^{b}$ | | | | | $e^{b2}$ |
| $d^{2}$ | | | | | $d^{2}$ |
| $c^{\#2}$ | | | | | $c^{\#2}$ |
| $c^{2}$ | | | | | $c^{2}$ |
| $b^{1}$ | | | | | $b^{1}$ |
| $b^{b1}$ | | | | | $b^{b1}$ |
| $a^{1}$ | | | | | $a^{1}$ |
| $g^{\#1}$ | | | | | $g^{\#1}$ |
| $g^{1}$ | | | | | $g^{1}$ |
| $f^{\#1}$ | | | | | $f^{\#1}$ |
| $f^{1}$ | | | | | $f^{1}$ |
| $e^{1}$ | | | | | $e^{1}$ |
| $e^{b1}$ | | | | | $e^{b1}$ |
| $d^{1}$ | | | | | $d^{1}$ |
| $c^{\#1}$ | | | | | $c^{\#1}$ |
| $c^{1}$ | | | | | $c^{1}$ |
| b | | | | | b |
| $b^{b}$ | | | | | $b^{b}$ |
| a | | | | | a |
| $g^{\#}$ | | | | | $g^{\#}$ |
| g | | | | | g |
| $f^{\#}$ | | | | | $f^{\#}$ |
| f | | | | | f |
| e | | | | | e |
| $e^{b}$ | 2 in 1 | | | | $e^{b}$ |
| d | 16 in 5 | 18 in 5 | | 7 in 2 | d |
| $c^{\#}$ | | | 2 in 1 | | $c^{\#}$ |
| c | | | 3 in 1 | | c |
| B | | | | | B |
| $B^{b}$ | | | | | $B^{b}$ |
| A | | | | | A |
| $G^{\#}$ | | | | 7 in 2 | $G^{\#}$ |
| G | | | | 3 in 1 | G |
| $F^{\#}$ | | 18 in 5 | | | $F^{\#}$ |
| F | | 3 in 1 | | | F |
| E | | | | | E |
| $E^{b}$ | | | | | $E^{b}$ |
| D | | | | | D |
| $C^{\#}$ | | | | | $C^{\#}$ |
| C | | | | | C |
| BB | | | | | BB |
| $BB^{b}$ | | | | | $BB^{b}$ |
| AA | | | | | AA |
| $GG^{\#}$ | | | | | $GG^{\#}$ |
| GG | | | 3 in 1 | 3 in 1 | GG |
| $FF^{\#}$ | | | | | |
| FF | 16 in 5 | 3 in 1 | | | |

## Appendix 3:

## DETERMINATION OF THE MARKING OUT OF THE POSITION OF THE BASS 8FT HITCHPINS AND THE 4FT TUNING PINS

**Table A3.1a**
**Distance of the bass 8ft hitchpins and the 4ft tuning pins from the spine of the C to d$^3$ models**

| | (1725) HH | | 1740b HH | | 1761b JH | | |
|---|---|---|---|---|---|---|---|
| | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | |
| | | | | | 40 | | e |
| e$^b$-e | 35 | | 32 | | 46 | | e$^b$ |
| d | 41½ | 37½ | 38½ | 34½ | 52 | 47 | d |
| c# | 48½ | 45 | 45½ | 42½ | 58 | 55 | c# |
| c | 54½ | 51 | 52 | 48 | 65 | 61 | c |
| B | 61 | 58 | 58 | 55 | 71 | 68 | B |
| B$^b$ | 67½ | 63½ | 64½ | 61 | 77 | 73 | B$^b$ |
| A | 74½ | 71½ | 71½ | 69 | 83 | 80 | A |
| G# | 81 | 77 | 78 | 75 | 89 | 85 | G# |
| G | 87½ | 85 | 85 | 82½ | 95 | 92½ | G |
| F# | 94½ | 91 | 91 | 88 | 101½ | 97½ | F# |
| F | 101 | 98½ | 98 | 96 | 107½ | 104 | F |
| E | 108 | 104 | 105 | 101½ | 113½ | 110 | E |
| E$^b$ | 114½ | 112 | 111½ | 109 | 119 | 117 | E$^b$ |
| D | 121 | 118 | 118 | 115 | 125 | 123 | D |
| C# | 128 | 125½ | 125 | 123 | 131½ | 129 | C# |
| C | 135 | 132 | 132 | 130 | 138 | 135 | C |

**Table A3.1b**
**Number of string pairs per Zoll for the C to d$^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | (1725) HH | | 1740b HH | | 1761b JH | | |
|---|---|---|---|---|---|---|---|
| | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | |
| | | | | | 16 in 4 | | e |
| e$^b$-e | 15 in 4$^2/_7$ | | 15 in 4$^2/_7$ | | | | e$^b$ |
| d | | 14 in 4 | | 14 in 4 | | 14 in 3½ | d |
| c# | | | | | | | c# |
| c | | | | | | | c |
| B | | | | | | | B |
| B$^b$ | | | | | | | B$^b$ |
| A | | | | | | | A |
| G# | | | | | | | G# |
| G | | | | | | | G |
| F# | | | | | | | F# |
| F | | | | | | | F |
| E | | | | | | | E |
| E$^b$ | | | | | | | E$^b$ |
| D | | | | | | | D |
| C# | | | | | | | C# |
| C | 15 in 4$^2/_7$ | 14 in 4 | 15 in 4$^2/_7$ | 14 in 4 | 16 in 4 | 14 in 3½ | C |

**Table A3.1c**
**Marking-out stick divisions for the C to $d^3$ models**

**Numbers of equally-spaced calibrations**
**in integral units of the Hamburg Zoll**

| | (1725) HH 8ft HITCH PINS | (1725) HH 4ft TUNING PINS | 1740b HH 8ft HITCH PINS | 1740b HH 4ft TUNING PINS | 1761b JH 8ft HITCH PINS | 1761b JH 4ft TUNING PINS | |
|---|---|---|---|---|---|---|---|
| | | | | | 4 in 1 | | e |
| $e^b$-e | 7 in 2 | | 7 in 2 | | | | $e^b$ |
| d | | 7 in 2 | | 7 in 2 | | 4 in 1 | d |
| c# | | | | | | | c# |
| c | | | | | | | c |
| B | | | | | | | B |
| $B^b$ | | | | | | | $B^b$ |
| A | | | | | | | A |
| G# | | | | | | | G# |
| G | | | | | | | G |
| F# | | | | | | | F# |
| F | | | | | | | F |
| E | | | | | | | E |
| $E^b$ | | | | | | | $E^b$ |
| D | | | | | | | D |
| C# | | | | | | | C# |
| C | 7 in 2 | 7 in 2 | 7 in 2 | 7 in 2 | 4 in 1 | 4 in 1 | C |

**Table A3.2a**
**Distance of the bass 8ft hitchpins and the 4ft tuning pins**
**from the spine of the FF to $f^3$ models**

| | 1742a HH 8ft HITCH PINS | 1742a HH 4ft TUNING PINS | 1744a HH 8ft HITCH PINS | 1744a HH 4ft TUNING PINS | 1763a JH 8ft HITCH PINS | 1763a JH 4ft TUNING PINS | 1767 JH 8ft HITCH PINS | 1767 JH 4ft TUNING PINS |
|---|---|---|---|---|---|---|---|---|
| e | 49 | | 50 | | 61 | | 61 | |
| $e^b$ | 54 | | 54 | | 66½ | | 66 | |
| d | 60 | 58½ | 60 | 58½ | 72 | | 72 | |
| c# | 65 | 63 | 65 | 63 | 77½ | | 77½ | |
| c | 71 | 70 | 70½ | 70 | 83½ | | 83 | 81½ |
| B | 76½ | 75 | 75½ | 74 | 89 | 87 | 88 | 85½ |
| $B^b$ | 81 | 80 | 82 | 80 | 95½ | 93 | 94½ | 92 |
| A | 86½ | 84½ | 86½ | 84 | 101 | 98 | 100 | 97 |
| G# | 91½ | 90 | 92 | 91 | 107 | 105 | 106½ | 105 |
| G | 97 | 95½ | 97 | 95 | 113 | 110 | 112½ | 110 |
| F# | 103 | 101½ | 103½ | 101½ | 120 | 117 | 118 | 116 |
| F | 108 | 106 | 109 | 106½ | 125½ | 123 | 123½ | 121 |
| E | 114½ | 113 | 114½ | 113 | 132 | 129 | 130½ | 128 |
| $E^b$ | 119½ | 117½ | 120½ | 118 | 137½ | 135 | 136 | 133 |
| D | 126 | 124 | 126 | 125 | 145 | 142 | 143 | 140 |
| C# | 131 | 129 | 131½ | 129½ | 151 | 148 | 148½ | 146 |
| C | 137 | 135 | 138½ | 136 | 158 | 154½ | 155 | 152½ |
| BB | 143 | 141 | 144 | 142 | 164 | 161 | 161½ | 158 |
| $BB^b$ | 149 | 147½ | 150 | 148 | 171 | 168 | 169 | 166 |
| AA | 156 | 153 | 157 | 154 | 178 | 175 | 175½ | 173 |
| GG# | 162 | 160 | 163 | 161 | 185 | 182 | 182½ | 179 |
| GG | 168 | 166 | 169½ | 167 | 192 | 188½ | 189 | 185 |
| FF# | 175 | 173½ | 175½ | 173 | 200 | 196½ | 196½ | 193 |
| FF | 181 | 179 | 182 | 179 | 206 | 203 | 203 | 200 |

## Table A3.2b
**Number of string pairs per Zoll for the FF to $f^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1742a HH 8ft HITCH PINS | 1742a HH 4ft TUNING PINS | 1744a HH 8ft HITCH PINS | 1744a HH 4ft TUNING PINS | 1763a JH 8ft HITCH PINS | 1763a JH 4ft TUNING PINS | 1767 JH 8ft HITCH PINS | 1767 JH 4ft TUNING PINS |
|---|---|---|---|---|---|---|---|---|
| e | 11 in $2^4/_9$ | | 11 in $2^4/_9$ | | 11 in $2^3/_4$ | | 11 in $2^3/_4$ | |
| $e^b$ | | | | | | | | |
| d | | 9 in 2 | | 9 in 2 | | | | |
| c# | | | | | | | | |
| c | | | | | | | | 7 in $1^3/_4$ |
| B | | | | | | 6 in $1\frac{1}{2}$ | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| G# | | | | | | | | |
| G | | | | | | | | |
| F# | 11 in $2^4/_9$ | 11 in $2^4/_9$ | 11 in $2^4/_9$ | 9 in 2 | 11 in $2^3/_4$ | 6 in $1\frac{1}{2}$ | 11 in $2^3/_4$ | 7 in $1^3/_4$ |
| F | 12 in 3 | 12 in 3 | 12 in 3 | 12 in 3 | 12 in $3^1/_3$ | 12 in $3^1/_3$ | 12 in $3^1/_3$ | 12 in $3^1/_3$ |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| C# | | | | | | | | |
| C | | | | | | | | |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| GG# | | | | | | | | |
| GG | | | | | | | | |
| FF# | | | | | | | | |
| FF | 12 in 3 | 12 in 3 | 12 in 3 | 12 in 3 | 12 in $3^1/_3$ | 12 in $3^1/_3$ | 12 in $3^1/_3$ | 12 in $3^1/_3$ |

## Table A3.2c
**Marking-out stick divisions for the FF to $f^3$ models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 1742a HH 8ft HITCH PINS | 1742a HH 4ft TUNING PINS | 1744a HH 8ft HITCH PINS | 1744a HH 4ft TUNING PINS | 1763a JH 8ft HITCH PINS | 1763a JH 4ft TUNING PINS | 1767 JH 8ft HITCH PINS | 1767 JH 4ft TUNING PINS |
|---|---|---|---|---|---|---|---|---|
| e | 9 in 2 | | 9 in 2 | | 4 in 1 | | 4 in 1 | |
| $e^b$ | | | | | | | | |
| d | | 9 in 2 | | 9 in 2 | | | | |
| c# | | | | | | | | |
| c | | | | | | | | 4 in 1 |
| B | | | | | | 4 in 1 | | |
| $B^b$ | | | | | | | | |
| A | | | | | | | | |
| G# | | | | | | | | |
| G | | | | | | | | |
| F# | 9 in 2 | 9 in 2 | 9 in 2 | 9 in 2 | 4 in 1 | 4 in 1 | 4 in 1 | 4 in1 |
| F | 4 in 1 | 4 in 1 | 4 in 1 | 4 in 1 | 18 in 5 | 18 in 5 | 18 in 5 | 18 in 5 |
| E | | | | | | | | |
| $E^b$ | | | | | | | | |
| D | | | | | | | | |
| C# | | | | | | | | |
| C | | | | | | | | |
| BB | | | | | | | | |
| $BB^b$ | | | | | | | | |
| AA | | | | | | | | |
| GG# | | | | | | | | |
| GG | | | | | | | | |
| FF# | | | | | | | | |
| FF | 4 in 1 | 4 in 1 | 4 in 1 | 4 in 1 | 18 in 5 | 18 in 5 | 18 in 5 | 18 in 5 |

**Table A3.3a**
**Distance of the bass 8ft hitchpins and the 4ft tuning pins from the spine of two unique models**

| | 1732b HH | | 1748 JH | | |
|---|---|---|---|---|---|
| | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | |
| | | | 47 | | f# |
| | | | 52 | | f |
| e | 44 | | 58 | | e |
| eb | 49 | | 63 | | eb |
| d | 54 | 53 | 69 | 68 | d |
| c# | 59 | 57 | 74 | 72 | c# |
| c | 64½ | 63 | 80 | 79 | c |
| B | 70 | 67½ | 86 | 83 | B |
| Bb | 75 | 73½ | 92 | 90 | Bb |
| A | 80 | 79 | 97½ | 94 | A |
| G# | 86 | 84½ | 103½ | 102 | G# |
| G | 91 | 88 | 110 | 107 | G |
| F# | 97 | 95 | 115½ | 114 | F# |
| F | 102 | 100 | 122 | 119 | F |
| E | 107½ | 105½ | 128 | 125½ | E |
| Eb | 113½ | 111 | 134½ | 132 | Eb |
| D | 119 | 117 | 141 | 138½ | D |
| C# | 124½ | 122 | 147 | 144 | C# |
| C | 131 | 129 | 153½ | 152 | C |
| BB | 137 | 135 | 160½ | 157 | BB |
| BBb | 143 | 140½ | 168 | 165 | BBb |
| AA | 149 | 148 | 174 | 171 | AA |
| GG# | 156 | 153½ | 181½ | 178½ | GG# |
| GG | 162½ | 161 | 188½ | 185 | GG |
| FF# | 169 | 166½ | | | |
| FF | 175 | 174 | | | |

**Table A3.3b**
**Number of string pairs per Zoll for two unique models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1732b HH | | 1748 JH | | |
|---|---|---|---|---|---|
| | 8ft HITCH PINS | 4ft TUNING PINS | 8ft HITCH PINS | 4ft TUNING PINS | |
| | | | 11 in 2 3/4 | | f# |
| | | | | | f |
| e | 16 in 3½ | | | | e |
| eb | | | | | eb |
| d | | 14 in 3 1/9 | | 7 in 1 3/4 | d |
| c# | | | | | c# |
| c | | | | | c |
| B | | | | | B |
| Bb | | | | | Bb |
| A | | | | | A |
| G# | | | 11 in 2 3/4 | 7 in 1 3/4 | G# |
| G | | | 12 in 3 1/3 | 12 in 3 1/3 | G |
| F# | | | | | F# |
| F | | | | | F |
| E | | | | | E |
| Eb | | | | | Eb |
| D | | | | | D |
| C# | 16 in 3½ | 14 in 3 1/9 | | | C# |
| C | 7 in 1 3/4 | 7 in 1 3/4 | | | C |
| BB | | | | | BB |
| BBb | | | | | BBb |
| AA | | | | | AA |
| GG# | | | | | GG# |
| GG | | | 12 in 3 1/3 | 12 in 3 1/3 | GG |
| FF# | | | | | |
| FF | 7 in 1 3/4 | 7 in 1 3/4 | | | |

**Table A3.3c**
**Marking-out stick divisions for two unique models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| | 1732b HH 8ft HITCH PINS | 1732b HH 4ft TUNING PINS | 1748 JH 8ft HITCH PINS | 1748 JH 4ft TUNING PINS | |
|---|---|---|---|---|---|
| | | | 4 in 1 | | f# |
| | | | | | f |
| e | 9 in 2 | | | | e |
| $e^b$ | | | | | $e^b$ |
| d | | 9 in 2 | | 4 in 1 | d |
| c# | | | | | c# |
| c | | | | | c |
| B | | | | | B |
| $B^b$ | | | | | $B^b$ |
| A | | | | | A |
| G# | | | 4 in 1 | 4 in 1 | G# |
| G | | | 18 in 5 | 18 in 5 | G |
| F# | | | | | F# |
| F | | | | | F |
| E | | | | | E |
| $E^b$ | | | | | $E^b$ |
| D | | | | | D |
| C# | 9 in 2 | 9 in 2 | | | C# |
| C | 4 in 1 | 4 in 1 | | | C |
| BB | | | | | BB |
| $BB^b$ | | | | | $BB^b$ |
| AA | | | | | AA |
| GG# | | | | | GG# |
| GG | | | 18 in 5 | 18 in 5 | GG |
| FF# | | | | | |
| FF | 4 in 1 | 4 in 1 | | | |

# Appendix 4:

# DETERMINATION OF THE MARKING OUT OF THE POSITION OF THE TENOR, ALTO AND TREBLE 8FT HITCHPINS

## Table A4.1a

**Distance of the tenor, alto and treble 8ft hitchpins from the left-hand end of the C to $d^3$ models**

| (1725) HH | | 1740b HH | | 1761b JH | |
|---|---|---|---|---|---|
| | | | 635 | | 630 |
| | | $d^3$ | 622 | $d^3$ | 615 |
| | 612 | | 609 | | |
| $c^{\#3}$-$d^3$ | 596 | $c^3$-$c^{\#3}$ | 594½ | $c^3$-$c^{\#3}$ | 587 |
| | 580½ | | 580 | | |
| $b^2$-$c^3$ | 565 | $b^{b2}$-$b^2$ | 565 | $b^{b2}$-$b^2$ | 558½ |
| | 549 | | 549 | | |
| $a^2$-$b^{b2}$ | 533½ | $a^2$ | 534 | $a^2$ | 530 |
| | 518½ | | 518½ | | |
| $g^2$-$g^{\#2}$ | 503 | $g^2$-$g^{\#2}$ | 503 | $g^2$-$g^{\#2}$ | 499 |
| | 487½ | | 487½ | | |
| $f^2$-$f^{\#2}$ | 472 | $f^2$-$f^{\#2}$ | 472 | $f^2$-$f^{\#2}$ | 470 |
| | 456½ | | 456 | | |
| $e^{b2}$-$e^2$ | 441 | $e^{b2}$-$e^2$ | 441 | $e^{b2}$-$e^2$ | 440½ |
| | 426 | | 425½ | | |
| $d^2$ | 410 | $d^2$ | 410½ | $d^2$ | 410 |
| | 394½ | | 395 | | |
| $c^2$-$c^{\#2}$ | 379 | $c^2$-$c^{\#2}$ | 379½ | $c^2$-$c^{\#2}$ | 379½ |
| | 364 | | 363½ | | |
| $b^{b1}$-$b^1$ | 348½ | $b^{b1}$-$b^1$ | 348½ | $b^{b1}$-$b^1$ | 350 |
| | 333 | | 332½ | | |
| $a^1$ | 317½ | $a^1$ | 317 | $a^1$ | 319 |
| | 302½ | | 302 | | |
| $g^1$-$g^{\#1}$ | 287½ | $g^1$-$g^{\#1}$ | 286 | $g^1$-$g^{\#1}$ | 288½ |
| | 272 | | 271 | | |
| $f^1$-$f^{\#1}$ | 256 | $f^1$-$f^{\#1}$ | 255 | $f^1$-$f^{\#1}$ | 258½ |
| | 240½ | | 239½ | | |
| $e^{b1}$-$e^1$ | 225 | $e^{b1}$-$e^1$ | 224 | $e^{b1}$-$e^1$ | 228½ |
| | 210 | | 209 | | |
| $d^1$ | 194½ | $d^1$ | 193½ | $d^1$ | 198 |
| | 178½ | | 178½ | | |
| $c^1$-$c^{\#1}$ | 163½ | $c^1$-$c^{\#1}$ | 163 | $c^1$-$c^{\#1}$ | 167½ |
| | 148 | | 147½ | | |
| $b^b$-$b$ | 132½ | $b^b$-$b$ | 132½ | $b^b$-$b$ | 137 |
| | 116½ | | 117 | | |
| $a$ | 101½ | $a$ | 101 | $a$ | 106½ |
| | 86 | | 86 | | |
| $g$-$g^\#$ | 70 | $g$-$g^\#$ | 70 | $g$-$g^\#$ | 75½ |
| | 54½ | | 54½ | | |
| $f$-$f^\#$ | 39 | $f$-$f^\#$ | 39½ | $f$-$f^\#$ | 45 |

**Table A4.1b**
**Number of string pairs per Zoll for the C to $d^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| (1725) HH | | 1740b HH | | 1761b JH | |
|---|---|---|---|---|---|
| | | $d^3$ | 39 in 25 | $d^3$ | 39 in $24^3/_8$ |
| $c^{\#3}$-$d^3$ | 37 in 24 | $c^3$-$c^{\#3}$ | | $c^3$-$c^{\#3}$ | |
| $b^2$-$c^3$ | | $b^{b2}$-$b^2$ | | $b^{b2}$-$b^2$ | |
| $a^2$-$b^{b2}$ | | $a^2$ | | $a^2$ | |
| $g^2$-$g^{\#2}$ | | $g^2$-$g^{\#2}$ | | $g^2$-$g^{\#2}$ | |
| $f^2$-$f^{\#2}$ | | $f^2$-$f^{\#2}$ | | $f^2$-$f^{\#2}$ | |
| $e^{b2}$-$e^2$ | | $e^{b2}$-$e^2$ | | $e^{b2}$-$e^2$ | |
| $d^2$ | | $d^2$ | | $d^2$ | |
| $c^2$-$c^{\#2}$ | | $c^2$-$c^{\#2}$ | | $c^2$-$c^{\#2}$ | |
| $b^{b1}$-$b^1$ | | $b^{b1}$-$b^1$ | | $b^{b1}$-$b^1$ | |
| $a^1$ | | $a^1$ | | $a^1$ | |
| $g^1$-$g^{\#1}$ | | $g^1$-$g^{\#1}$ | | $g^1$-$g^{\#1}$ | |
| $f^1$-$f^{\#1}$ | | $f^1$-$f^{\#1}$ | | $f^1$-$f^{\#1}$ | |
| $e^{b1}$-$e^1$ | | $e^{b1}$-$e^1$ | | $e^{b1}$-$e^1$ | |
| $d^1$ | | $d^1$ | | $d^1$ | |
| $c^1$-$c^{\#1}$ | | $c^1$-$c^{\#1}$ | | $c^1$-$c^{\#1}$ | |
| $b^b$-b | | $b^b$-b | | $b^b$-b | |
| a | | a | | a | |
| g-$g^\#$ | | g-$g^\#$ | | g-$g^\#$ | |
| f-$f^\#$ | 37 in 24 | f-$f^\#$ | 39 in 25 | f-$f^\#$ | 39 in $24^3/_8$ |

**Table A4.1c**
**Marking-out stick divisions for the C to $d^3$ models**

**Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll**

| (1725) HH | | 1740b HH | | 1761b JH | |
|---|---|---|---|---|---|
| | | $d^3$ | 39 in 25 | $d^3$ | 8 in 5 |
| $c^{\#3}$-$d^3$ | 37 in 24 | $c^3$-$c^{\#3}$ | | $c^3$-$c^{\#3}$ | |
| $b^2$-$c^3$ | | $b^{b2}$-$b^2$ | | $b^{b2}$-$b^2$ | |
| $a^2$-$b^{b2}$ | | $a^2$ | | $a^2$ | |
| $g^2$-$g^{\#2}$ | | $g^2$-$g^{\#2}$ | | $g^2$-$g^{\#2}$ | |
| $f^2$-$f^{\#2}$ | | $f^2$-$f^{\#2}$ | | $f^2$-$f^{\#2}$ | |
| $e^{b2}$-$e^2$ | | $e^{b2}$-$e^2$ | | $e^{b2}$-$e^2$ | |
| $d^2$ | | $d^2$ | | $d^2$ | |
| $c^2$-$c^{\#2}$ | | $c^2$-$c^{\#2}$ | | $c^2$-$c^{\#2}$ | |
| $b^{b1}$-$b^1$ | | $b^{b1}$-$b^1$ | | $b^{b1}$-$b^1$ | |
| $a^1$ | | $a^1$ | | $a^1$ | |
| $g^1$-$g^{\#1}$ | | $g^1$-$g^{\#1}$ | | $g^1$-$g^{\#1}$ | |
| $f^1$-$f^{\#1}$ | | $f^1$-$f^{\#1}$ | | $f^1$-$f^{\#1}$ | |
| $e^{b1}$-$e^1$ | | $e^{b1}$-$e^1$ | | $e^{b1}$-$e^1$ | |
| $d^1$ | | $d^1$ | | $d^1$ | |
| $c^1$-$c^{\#1}$ | | $c^1$-$c^{\#1}$ | | $c^1$-$c^{\#1}$ | |
| $b^b$-b | | $b^b$-b | | $b^b$-b | |
| a | | a | | a | |
| g-g# | | g-g# | | g-g# | |
| f-f# | 37 in 24 | f-f# | 39 in 25 | f-f# | 8 in 5 |

**Table A4.2a**
**Distance of the tenor, alto and treble 8ft hitchpins from the left-hand end of the FF to $f^3$ models**

| | 1742a HH | 1744a HH | 1755 JH | 1763a JH |
|---|---|---|---|---|
| $f^3$ | 776 | 777 | 790 | 774½ |
| $e^3$ | 756 | 757 | 772 | 755 |
| $e^{b3}$ | 736 | 736½ | 753 | 736 |
| $d^3$ | 716 | 716½ | 735 | 716 |
| $c\#^3$ | 695½ | 696½ | 715 | 697 |
| $c^3$ | 675 | 676½ | 694½ | 677 |
| $b^2$ | 655 | 656½ | 674 | 657½ |
| $b^{b2}$ | 635 | 636 | 653 | 633 |
| $a^2$ | 615 | 616 | 631½ | 618 |
| $g\#^2$ | 595 | 596 | 611½ | 598 |
| $g^2$ | 575 | 576 | 590 | 578 |
| $f\#^2$ | 555 | 556 | 569½ | 558 |
| $f^2$ | 534½ | 535½ | 549 | 539 |
| $e^2$ | 514 | 515½ | 528 | 518 |
| $e^{b2}$ | 494 | 495½ | 507 | 498 |
| $d^2$ | 474 | 475½ | 486½ | 478 |
| $c\#^2$ | 454 | 455 | 465 | 458 |
| $c^2$ | 434 | 435 | 444 | 437½ |
| $b^1$ | 414 | 415 | 423½ | 417 |
| $b^{b1}$ | 393½ | 389½ | 402½ | 397 |
| $a^1$ | 373½ | 374 | 382 | 376½ |
| $g\#^1$ | 353½ | 354 | 361½ | 356 |
| $g^1$ | 333½ | 333 | 340½ | 335 |
| $f\#^1$ | 313½ | 314 | 320 | 315 |
| $f^1$ | 293 | 294 | 299 | 295 |
| $e^1$ | 273 | 275 | 277½ | 275 |
| $e^{b1}$ | 253 | 254 | 256½ | 254 |
| $d^1$ | 233 | 234 | 235½ | 233 |
| $c\#^1$ | 212½ | 213 | 215 | 212 |
| $c^1$ | 192 | 193 | 194 | 192 |
| b | 172 | 173½ | 172½ | 171 |
| $b^b$ | 152 | 153 | 152 | 150 |
| a | 132 | 133 | 131 | 130 |
| g# | 112 | 113 | 110 | 109 |
| g | 91½ | 93 | 95 | 88 |
| f# | 71½ | 73 | 68 | 67 |
| f | 51½ | 52 | 48 | 47 |

**Table A4.2b**
**Number of string pairs per Zoll in each row for the FF to $f^3$ models**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1742a HH | 1744a HH | 1755 JH | 1763a JH |
|---|---|---|---|---|
| $f^3$ | 36 in $30^6/_{19}$ | 36 in $30^6/_{19}$ | 36 in 31 | 36 in $30^6/_{13}$ |
| $e^3$ | | | | |
| $e^{b3}$ | | | | |
| $d^3$ | | | | |
| $c^{\#3}$ | | | | |
| $c^3$ | | | | |
| $b^2$ | | | | |
| $b^{b2}$ | | | | |
| $a^2$ | | | | |
| $g^{\#2}$ | | | | |
| $g^2$ | | | | |
| $f^{\#2}$ | | | | |
| $f^2$ | | | | |
| $e^2$ | | | | |
| $e^{b2}$ | | | | |
| $d^2$ | | | | |
| $c^{\#2}$ | | | | |
| $c^2$ | | | | |
| $b^1$ | | | | |
| $b^{b1}$ | | | | |
| $a^1$ | | | | |
| $g^{\#1}$ | | | | |
| $g^1$ | | | | |
| $f^{\#1}$ | | | | |
| $f^1$ | | | | |
| $e^1$ | | | | |
| $e^{b1}$ | | | | |
| $d^1$ | | | | |
| $c^{\#1}$ | | | | |
| $c^1$ | | | | |
| b | | | | |
| $b^b$ | | | | |
| a | | | | |
| $g^\#$ | | | | |
| g | | | | |
| $f^\#$ | | | | |
| f | 36 in $30^6/_{19}$ | 36 in $30^6/_{19}$ | 36 in 31 | 36 in $30^6/_{13}$ |

## Table A4.2c
## Marking-out stick divisions for the FF to $f^3$ models

### Numbers of equally-spaced calibrations in integral units of the Hamburg Zoll

| | 1742a HH | 1744a HH | 1755 JH | 1763a JH |
|---|---|---|---|---|
| $f^3$ | 19 in 16 | 19 in 16 | 36 in 31 | 13 in 11 |
| $e^3$ | | | | |
| $e^{b3}$ | | | | |
| $d^3$ | | | | |
| $c^{\#3}$ | | | | |
| $c^3$ | | | | |
| $b^2$ | | | | |
| $b^{b2}$ | | | | |
| $a^2$ | | | | |
| $g^{\#2}$ | | | | |
| $g^2$ | | | | |
| $f^{\#2}$ | | | | |
| $f^2$ | | | | |
| $e^2$ | | | | |
| $e^{b2}$ | | | | |
| $d^2$ | | | | |
| $c^{\#2}$ | | | | |
| $c^2$ | | | | |
| $b^1$ | | | | |
| $b^{b1}$ | | | | |
| $a^1$ | | | | |
| $g^{\#1}$ | | | | |
| $g^1$ | | | | |
| $f^{\#1}$ | | | | |
| $f^1$ | | | | |
| $e^1$ | | | | |
| $e^{b1}$ | | | | |
| $d^1$ | | | | |
| $c^{\#1}$ | | | | |
| $c^1$ | | | | |
| b | | | | |
| $b^b$ | | | | |
| a | | | | |
| $g^\#$ | | | | |
| g | | | | |
| $f^\#$ | | | | |
| f | 19 in 16 | 19 in 16 | 36 in 31 | 13 in 11 |

**Table A4.3a**
**Distance of the tenor, alto and treble 8ft hitchpins from the left-hand end for two unique models**

| | 1732b HH | 1748 JH | |
|---|---|---|---|
| $d^3$ | 736 | 694 | $d^3$ |
| $c^{\#3}$ | 717 | 674½ | $c^{\#3}$ |
| $c^3$ | 697 | 654 | $c^3$ |
| $b^2$ | 677 | 632½ | $b^2$ |
| $b^{b2}$ | 658 | 612 | $b^{b2}$ |
| $a^2$ | 637 | 591 | $a^2$ |
| $g^{\#2}$ | 617 | 570 | $g^{\#2}$ |
| $g^2$ | 598 | 549 | $g^2$ |
| $f^{\#2}$ | 578½ | 528 | $f^{\#2}$ |
| $f^2$ | 558 | 507 | $f^2$ |
| $e^2$ | 536 | 486½ | $e^2$ |
| $e^{b2}$ | 515 | 465 | $e^{b2}$ |
| $d^2$ | 494 | 443½ | $d^2$ |
| $c^{\#2}$ | 471 | 423 | $c^{\#2}$ |
| $c^2$ | 451 | 402 | $c^2$ |
| $b^1$ | 428 | 381½ | $b^1$ |
| $b^{b1}$ | 407 | 360½ | $b^{b1}$ |
| $a^1$ | 385 | 340 | $a^1$ |
| $g^{\#1}$ | 364 | 319 | $g^{\#1}$ |
| $g^1$ | 343 | 298 | $g^1$ |
| $f^{\#1}$ | 321 | 277 | $f^{\#1}$ |
| $f^1$ | 300½ | 257 | $f^1$ |
| $e^1$ | 279 | 235½ | $e^1$ |
| $e^{b1}$ | 257 | 214½ | $e^{b1}$ |
| $d^1$ | 236 | 193½ | $d^1$ |
| $c^{\#1}$ | 214½ | 172½ | $c^{\#1}$ |
| $c^1$ | 193 | 152 | $c^1$ |
| b | 171 | 131½ | b |
| $b^b$ | 150 | 110 | $b^b$ |
| a | 128 | 90 | a |
| $g^\#$ | 107 | 69 | $g^\#$ |
| g | 85 | 48 | g |
| $f^\#$ | 63 | | |
| f | 35 | | |

**Table A4.3b**
**Number of string pairs per Zoll for two unique instruments**

**Numbers of equally-spaced string pairs and the distance in Zolle occupied by them**

| | 1732b HH<br>in single row | 1748 JH<br>in each row | |
|---|---|---|---|
| $d^3$ | 67 in $30^5/_{11}$ | 31 in $27^1/_8$ | $d^3$ |
| $c\#^3$ | | | $c\#^3$ |
| $c^3$ | | | $c^3$ |
| $b^2$ | | | $b^2$ |
| $b^{b2}$ | | | $b^{b2}$ |
| $a^2$ | | | $a^2$ |
| $g\#^2$ | | | $g\#^2$ |
| $g^2$ | | | $g^2$ |
| $f\#^2$ | | | $f\#^2$ |
| $f^2$ | | | $f^2$ |
| $e^2$ | | | $e^2$ |
| $e^{b2}$ | | | $e^{b2}$ |
| $d^2$ | | | $d^2$ |
| $c\#^2$ | | | $c\#^2$ |
| $c^2$ | | | $c^2$ |
| $b^1$ | | | $b^1$ |
| $b^{b1}$ | | | $b^{b1}$ |
| $a^1$ | | | $a^1$ |
| $g\#^1$ | | | $g\#^1$ |
| $g^1$ | | | $g^1$ |
| $f\#^1$ | | | $f\#^1$ |
| $f^1$ | | | $f^1$ |
| $e^1$ | | | $e^1$ |
| $e^{b1}$ | | | $e^{b1}$ |
| $d^1$ | | | $d^1$ |
| $c\#^1$ | | | $c\#^1$ |
| $c^1$ | | | $c^1$ |
| b | | | b |
| $b^b$ | | | $b^b$ |
| a | | | a |
| g# | | | g# |
| g | | 31 in $27^1/_8$ | g |
| f# | | | |
| f | 67 in $30^5/_{11}$ | | |

**Table 4.3c**
**Marking-out stick divisions**

**Numbers of equally-spaced calibrations**
**in integral units of the Hamburg Zoll for two unique instruments**

| | 1732b HH | 1748 JH | |
|---|---|---|---|
| $d^3$ | 11 in 5 | 8 in 7 | $d^3$ |
| $c^{\#3}$ | | | $c^{\#3}$ |
| $c^3$ | | | $c^3$ |
| $b^2$ | | | $b^2$ |
| $b^{b2}$ | | | $b^{b2}$ |
| $a^2$ | | | $a^2$ |
| $g^{\#2}$ | | | $g^{\#2}$ |
| $g^2$ | | | $g^2$ |
| $f^{\#2}$ | | | $f^{\#2}$ |
| $f^2$ | | | $f^2$ |
| $e^2$ | | | $e^2$ |
| $e^{b2}$ | | | $e^{b2}$ |
| $d^2$ | | | $d^2$ |
| $c^{\#2}$ | | | $c^{\#2}$ |
| $c^2$ | | | $c^2$ |
| $b^1$ | | | $b^1$ |
| $b^{b1}$ | | | $b^{b1}$ |
| $a^1$ | | | $a^1$ |
| $g^{\#1}$ | | | $g^{\#1}$ |
| $g^1$ | | | $g^1$ |
| $f^{\#1}$ | | | $f^{\#1}$ |
| $f^1$ | | | $f^1$ |
| $e^1$ | | | $e^1$ |
| $e^{b1}$ | | | $e^{b1}$ |
| $d^1$ | | | $d^1$ |
| $c^{\#1}$ | | | $c^{\#1}$ |
| $c^1$ | | | $c^1$ |
| b | | | b |
| $b^b$ | | | $b^b$ |
| a | | | a |
| $g^\#$ | | | $g^\#$ |
| g | | 8 in 7 | g |
| $f^\#$ | | | |
| f | 11 in 5 | | |

## Appendix 5:

## TANGENT HEAD WIDTH MEASUREMENTS

| | C to $d^3$ | FF to $d^3$ | GG to $d^3$ | FF to $f^3$ | | | |
|---|---|---|---|---|---|---|---|
| | 1740b HH | 1732b HH | 1748 JH | 1742a HH | 1742b HH | 1760b JH | 1767 JH |
| $f^3$ | | | | 4.0 | 3.6 | 4.3 | 4.0 |
| $e^3$ | | | | 3.9 | 3.7 | 4.1 | 4.2 |
| $e^{b3}$ | | | | 4.0 | 3.7 | 4.3 | 4.3 |
| $d^3$ | 5.1 | 3.6 | 4.4 | 4.2 | 3.8 | 4.2 | 4.2 |
| $c^{\#3}$ | 4.8 | not original | 4.3 | 4.2 | 4.1 | 4.2 | 4.5 |
| $c^3$ | 4.6 | 3.9 | 4.2 | 4.1 | 4.4 | 4.5 | 4.5 |
| $b^2$ | 5.0 | 3.9 | 4.4 | 4.3 | 4.2 | 4.7 | 4.5 |
| $b^{b2}$ | 4.7 | 3.9 | 4.5 | 4.4 | 4.3 | 4.5 | 4.5 |
| $a^2$ | 4.5 | 3.9 | 4.4 | 4.4 | 4.3 | 4.7 | 4.4 |
| $g^{\#2}$ | 5.3 | 4.0 | 4.5 | 4.5 | 4.4 | 4.7 | 4.6 |
| $g^2$ | 5.2 | 4.2 | 4.3 | 4.6 | 4.4 | 4.7 | 4.8 |
| $f^{\#2}$ | 5.1 | 4.2 | 4.3 | 4.7 | 4.5 | 4.5 | 4.7 |
| $f^2$ | 5.2 | 4.2 | 4.5 | 4.7 | 4.6 | 4.8 | 4.7 |
| $e^2$ | 5.3 | 4.5 | 4.3 | 4.8 | 4.5 | 4.9 | 4.5 |
| $e^{b2}$ | 5.3 | 4.5 | 4.2 | 4.7 | 4.4 | 4.8 | 4.7 |
| $d^2$ | 5.0 | 4.5 | 4.3 | 4.6 | 4.6 | 4.8 | 4.7 |
| $c^{\#2}$ | 5.4 | 4.7 | 4.4 | 4.7 | 4.6 | 4.7 | 4.5 |
| $c^2$ | 5.5 | 4.5 | 4.4 | 4.8 | 4.6 | 4.8 | 4.7 |
| $b^1$ | 5.2 | not original | 4.3 | 4.9 | 4.9 | 4.6 | 4.9 |
| $b^{b1}$ | 5.3 | 4.7 | 4.4 | 4.9 | 5.0 | 4.7 | 4.8 |
| $a^1$ | 5.5 | 4.7 | 4.5 | 4.9 | 5.0 | 4.8 | 4.6 |
| $g^{\#1}$ | 5.5 | not original | 4.3 | 4.9 | 4.9 | 4.8 | 4.9 |
| $g^1$ | 5.7 | 4.7 | 4.3 | 5.1 | 5.0 | 4.9 | 4.7 |
| $f^{\#1}$ | 5.9 | 4.7 | 4.5 | 4.8 | 4.9 | 4.8 | 4.9 |
| $f^1$ | 5.7 | 4.7 | 4.2 | 4.7 | 5.1 | 4.8 | 4.7 |
| $e^1$ | 5.2 | 4.6 | 4.2 | 4.8 | 5.1 | 5.0 | 4.9 |
| $e^{b1}$ | 5.7 | 4.7 | 4.2 | 4.9 | 5.0 | 4.8 | 4.8 |
| $d^1$ | 5.2 | 4.6 | 4.1 | 4.9 | 5.0 | 5.0 | 4.7 |
| $c^{\#1}$ | 5.6 | 4.7 | 4.0 | 5.0 | 4.8 | 5.2 | 4.8 |
| $c^1$ | 5.6 | 4.7 | 4.2 | 4.9 | 4.7 | 5.0 | 4.5 |
| b | 5.7 | 4.7 | 4.3 | 4.9 | 4.8 | 5.0 | 4.5 |
| $b^b$ | 5.5 | 4.6 | 4.4 | 4.8 | 4.7 | 5.0 | 4.7 |
| a | 5.8 | 4.6 | 4.4 | 4.9 | 4.8 | 5.1 | 4.7 |
| g# | 5.5 | 4.7 | 4.9 | 4.8 | 4.7 | 4.9 | 4.8 |
| g | 5.8 | 4.6 | 4.6 | 4.7 | 4.5 | 5.0 | 4.8 |
| f# | 5.7 | 4.8 | 4.7 | 4.7 | 4.8 | 5.0 | 4.9 |
| f | 6.0 | 5.0 | 4.9 | 4.8 | 4.7 | 5.4 | 4.8 |
| e | 6.2 | 5.4 | 5.7 | 5.3 | 5.5 | 5.6 | 5.1 |
| $e^b$ | 5.9 | 5.3 | 5.5 | 5.2 | 5.2 | 5.7 | 5.1 |
| d | 6.6 | 5.3 | 5.7 | 5.3 | 5.3 | 5.7 | 5.4 |
| c# | 6.7 | 5.4 | 5.6 | 5.3 | 5.3 | 6.0 | 5.5 |
| c | 6.8 | 5.4 | 5.5 | 5.4 | 5.5 | 5.9 | 5.6 |
| B | 7.4 | 5.3 | 5.8 | 5.5 | 5.4 | 6.0 | 5.5 |
| $B^b$ | 7.3 | 5.5 | 5.7 | 5.5 | 5.4 | 6.4 | 5.5 |
| A | 7.3 | 5.5 | 5.9 | 5.6 | 5.4 | 6.2 | 5.6 |
| G# | 7.4 | 5.6 | 6.0 | 5.6 | 5.4 | 6.0 | 5.8 |
| G | 7.3 | 5.7 | 6.4 | 5.6 | 5.4 | 6.0 | 6.3 |
| F# | 6.8 | 6.3 | 6.5 | 5.5 | 5.8 | 6.1 | 6.4 |
| F | 6.9 | 6.0 | 6.4 | 5.6 | 5.6 | 6.3 | 6.4 |
| E | 7.5 | 6.1 | 6.4 | 5.6 | 5.6 | 6.3 | 6.2 |
| $E^b$ | 7.3 | 6.0 | 6.5 | 5.8 | 5.7 | 6.3 | 6.1 |
| D | 7.2 | 6.2 | 6.6 | 6.1 | 5.4 | 6.5 | 6.5 |
| C# | 7.5 | 6.4 | 6.5 | 5.8 | 5.5 | 6.5 | 6.5 |
| C | 7.1 | 6.2 | 6.6 | 6.0 | 5.8 | 6.6 | 6.7 |
| BB | | 6.6 | 6.6 | 6.4 | 5.8 | 7.2 | 6.6 |
| $BB^b$ | | 6.6 | 6.8 | 6.4 | 6.1 | 7.4 | 7.1 |
| AA | | 6.7 | 7.3 | 6.6 | 6.0 | 7.1 | 7.1 |
| GG# | | 6.8 | 7.5 | 6.5 | 5.9 | 7.3 | 7.6 |
| GG | | 6.5 | 7.6 | 6.6 | 6.2 | 7.9 | 7.4 |
| FF# | | 6.9 | | 6.4 | 6.4 | 7.7 | 7.5 |
| FF | | 7.6 | | 7.2 | 6.4 | 7.9 | 7.7 |

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